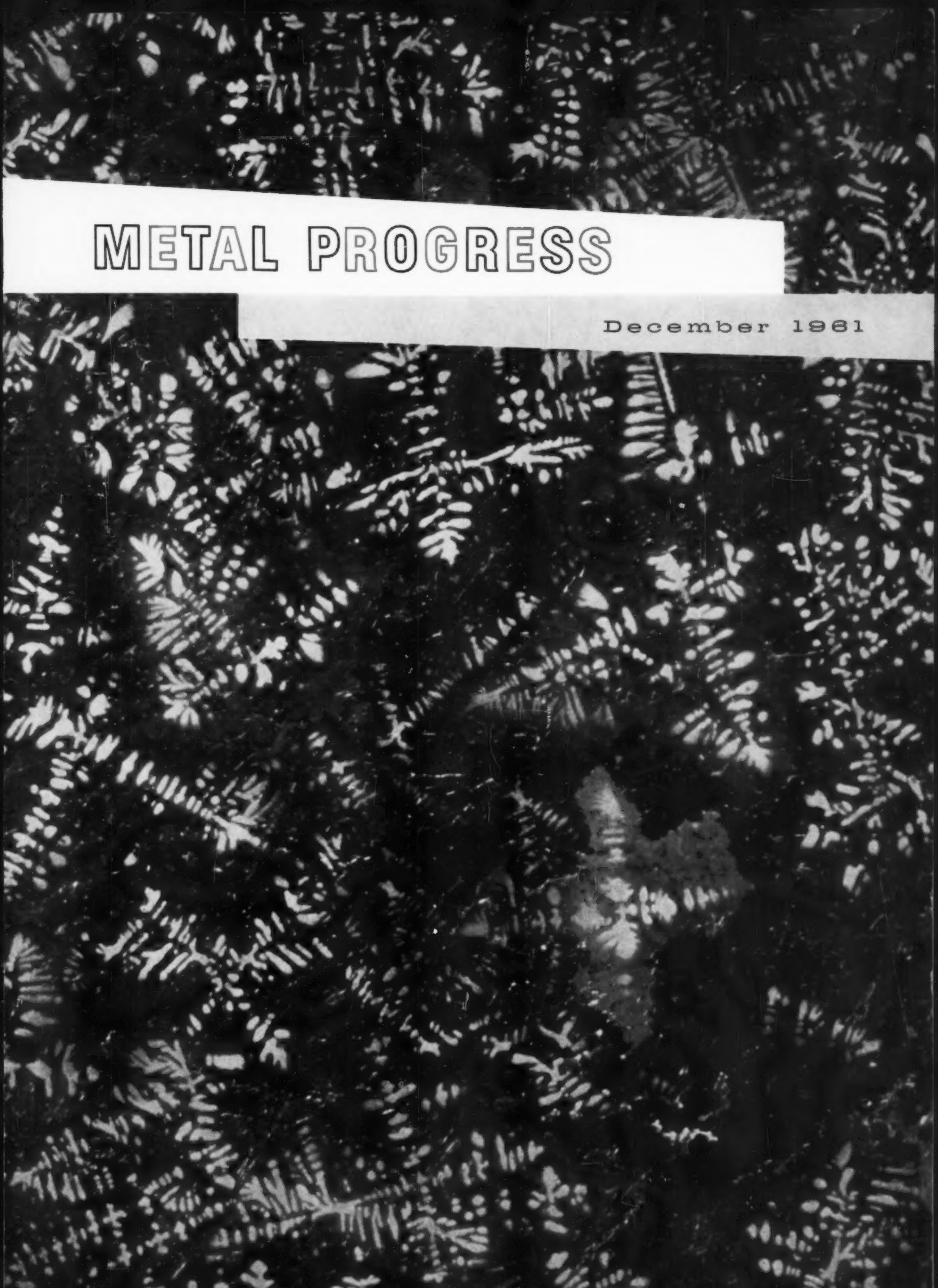
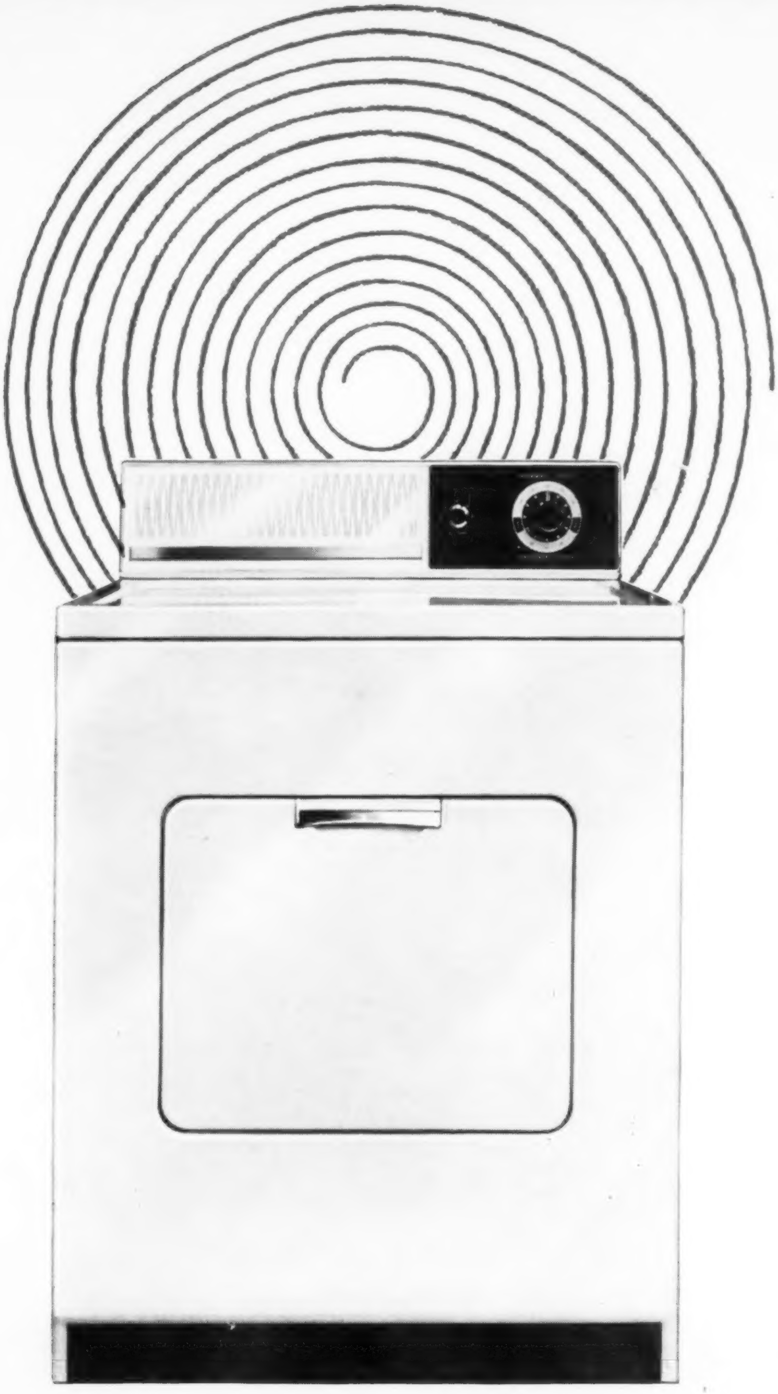
METAL PROGRESS

December 1961





METAL PROGRESS

THE MAGAZINE OF MATERIALS AND PROCESS ENGINEERING

December 1961 . . . Volume 80, No. 6

COVER: The micrograph of an aluminum casting alloy on this month's cover was aptly named "Snowflakes on the Grass" by one of our editors. Photographed by CLAYTON MCNEIL of Chrysler Corp., it was an entry in the 15th A.S.M. Metallographic Exhibit. More details are given on p. 84.

Technical News in Brief

New Nonmagnetic Alloys Achieve High Hardness. . . . Punch Card Controls for Heat Treating. . . . Vacuum Induction Furnaces Are Getting Bigger. . . . Missile Chamber Skirt Fabricated by Spin Forging. . . . Oxygen Converters Produce 240 Tons of Steel per Hour. . . . Beryllides – New High-Temperature Materials. . . . Continuous Vacuum Furnace Processes Diodes. . . . Progress in Nonmetallic Materials. . . . International Progress and Forecast Issue Next Month

Progress in High-Temperature Materials

How to Make Reliable Seam and Spot Welds in René 41, by B. M. Wahlin and D. R. Coles 67

High-quality seam and spot welds in René 41 can be made consistently if precautions based on the metallurgical behavior of the alloy are taken into account.

Two Superalloys for Jet Engines:

Udimet 700, a Wrought Alloy, by I. S. Servi and W. J. Boesch 73

Bar and billet stock of this alloy is available commercially, and sheet and wrought shapes are being tested for new applications.

IN-100, a Cast Alloy, by S. F. Sternasty and E. W. Ross 73

The reported high stress-rupture strength of this alloy has stimulated a detailed evaluation of its producibility and properties. Results indicate that it can be used for turbine blades and other high-temperature applications for advanced jet engines.

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Vacuum Melting Improves Properties of H11 Steel, by P. E. Ruff and R. W. Steur 79

Consumable-electrode, vacuum-melted H11 steel is probably cleaner than its air-melted counterpart, but the size, shape and distribution of inclusions may have a more important effect on properties than do quantitative differences.

The Effects of Strain Rate and Temperature on Metals, by J. R. Kattus 85

Under conditions of rapid loading and short times at temperature, strengthening mechanisms – such as precipitation and work hardening or martensitic transformation – retain some of their effectiveness to much higher temperatures.

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How Composition Affects the Properties of Ductile Iron, by J. F. Wallace and L. J. Ebert 92

In the heat treatment of ductile iron, silicon increases the critical temperature range and enhances the tempering response, while manganese decreases the critical temperatures, improves hardenability and reduces tempering response.

Cast Chromium Nickel Stainless Steels for Superior Resistance to Stress Corrosion, by M. G. Fontana, F. H. Beck and J. W. Flowers 99

Higher strength and improved resistance to stress corrosion can be obtained from stainless alloy castings through control of the amount of ferrite in the material.

Materials Research in Europe, by Samuel L. Hoyt 103

". . . as staff representative of the Research and Engineering Div. of our Department of Defense, I found a strong interest in current problems and a common bond between scientific and technical personnel, both with us in the United States and with each other."

Automatic Forging of Steel Gears, by John G. Wilson 108

An automatic rotary hearth furnace teamed with a 6000-ton mechanical press provides faster, controlled heating for improved forgeability, lower costs, and less scaling.

Guest Critical Point

Is 1700° F. the Only Temperature for Grain Size Control?, by H. W. McQuaid 65

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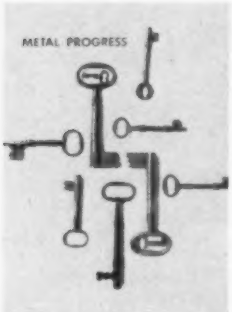
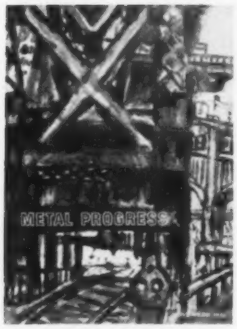
PRESS BREAKS





The four *Metal Progress* covers pictured in miniature at the left are the winners (in descending order, top to bottom) of the ten judged in the *Metal Progress* cover contest held at the A.S.M. Metal Show in Detroit. Started five years ago, this contest has become an annual feature at the A.S.M. booth. A dozen or so *Metal Progress* covers are usually displayed – some are scheduled for a forthcoming issue while others are art work for possible future covers, designed by students at the Cleveland Institute of Art in the cover design contest sponsored each year by *Metal Progress.* Visitors to the booth judge the covers (each marked by a number) and list their preference; the winner is the one whose rating corresponds most closely to the total ballot preference. This year's winner (out of 607 ballots cast) is ASMer Alfred E. Hilgeman, technical director, General Foundry & Mfg. Co., Flint, Mich. A large silver bowl, suitably engraved, was presented to Mr. Hilgeman at the November 14 meeting of the Saginaw Valley Chapter on behalf of *Metal Progress,* by Richard D. Chapman, a member of A.S.M.'s Technical Council and representative on the *Metal Progress* Editorial Advisory Committee.

And speaking of *Metal Progress* covers, this December issue with the micrograph on the cover portraying "Snowflakes on the Grass" is our way of wishing you a Merry Christmas. As this column goes to press, the Staff is hard at work on the January International issue which is devoted to World Progress in Materials and Process Engineering. This first issue of 1962 will come to you as our New Year's greeting and it will also feature "Technology Forecast – '62" which is planned as a concise report on what to expect in metals technology in the months ahead.

THE EDITORS

HANDY ALLOY DATA SHEET

HANDY & HARMAN ENGINEERING DEPARTMENT
82 FULTON STREET, NEW YORK 38, N.Y.

TEC and TEC-Z

...How to choose between a soft solder and a brazing alloy

Handy & Harman provides *two* alloys that fit between "something stronger than the average soft solder but not as strong as a silver-brazing alloy." They are named TEC and TEC-Z and their flow points are intermediate between soft solders and silver-brazing alloys. Joints made by these alloys are strong in straight tension or shear. For instance, butt joints of cold-worked copper can be made having a tensile strength of about 25,000 psi. This is approximately 10,000 psi. more than can be obtained with tin-lead soft solders. TEC joints retain their strength at elevated temperatures much better than the tin-lead soft solders. As shown in the table below, the strength of the solder itself at 425° F is about the same as a 50% tin–50% lead solder at room temperature in short-time tensile tests.

Applications—One example is a thermostatic bellows where the operating temperature is too high for soft solders (tin-lead), yet requires a joining medium which will not anneal the bellows. Another use is gun parts which require joint strength at higher than soft-solder operating temperatures *plus* corrosion resistance to solutions used in cleaning and blackening. Also for lamp bulb bases operating at approximately 350°-500° F. Automotive applications and heat exchangers. TEC conforms to Government Specifications Mil-S-19234 (Nord); both TEC and TEC-Z are available in sheet, wire, powder, and preforms to specifications.

NOMINAL COMPOSITIONS

	TEC	TEC-Z
Silver	5% plus or minus 0.5%	5% plus or minus 0.5%
Zinc		16.6% plus or minus 0.5%
Cadmium	95% plus or minus 0.5%	78.4% plus or minus 0.5%

PHYSICAL PROPERTIES

	TEC	TEC-Z
Color	White	White
Melting Point	640° F	480° F
Flow Point	740° F	600° F
Density (Troy oz/cu in.)	4.60	4.53
Electrical Conductivity (Cu=100)	22.0%	20.6%
Electrical Resistivity (Microhm-cm)	7.9	8.4

STRENGTH COMPARISON TEC vs. Pb-SN

	TENSILE STRENGTH LBS/SQ IN. TEC	TENSILE STRENGTH LBS/SQ IN. Pb-SN
ROOM	16,400	2,500
300° F	4,400	650
425° F	2,600	Melts
500° F	1,700	

The information and data on this page are available in our Handy Alloy Data Sheet. Ask for "TEC." Handy & Harman, 850 Third Ave., New York 22, N.Y.

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New Nonmagnetic Alloys Achieve High Hardness

A new system of NiTi-base alloys may solve some troublesome problems in nonmagnetic applications where low permeability, hardness, fabricability, and corrosion and abrasion resistance are required. These nonmagnetic alloys (Nitinol) of suitable composition can be hardened to Rockwell C-62. Although $NiTi_2$ and Ni_3Ti phases may be associated, the most phase-pure NiTi composition contains 54.5% Ni by wt. and has a body-centered cubic crystal structure. Its melting point is 1300° C. (2370° F.). Room temperature properties of hot worked NiTi phase are: elongation, 15%; Charpy impact strength, 28 ft-lb.; tensile strength, 124,000 psi. Hot hardness measurements indicated a secondary hardening peak at 427 to 482° C. (800 to 900° F.). Oxidation resistance in that temperature range is excellent. NiTi-base alloys are paramagnetic with a permeability of <1.002 over a wide temperature range. Permeability of this material is stable with variations in working and heat treatment. Specific gravity is 6.45.

NiTi alloys when quenched in water from 1000° C. (1830° F.) hardened to Rockwell C-62. It is believed that in quenching, a finely distributed Ni_3Ti phase becomes trapped in a NiTi matrix. In the quenched nickel-rich NiTi alloys a marked improvement was noted over the phase-pure NiTi alloys up to 480° C. (900° F.). The NiTi alloy with 54.5% Ni by wt. at room temperature shows excellent damping capacity; when heated slightly above room temperature, the damping capacity decreases significantly.

Properties of the NiTi-base alloys lend themselves to nonmagnetic tools in marine mine disposal applications and in various components of magnetometers, mine laying and servicing craft. The significant variation in damping characteristics with temperature indicates a possible application of NiTi alloys in temperature-sensing devices.

This new class of nickel-titanium alloys was developed by W. J. Buehler and R. C. Wiley at the U. S. Naval Ordnance Laboratory, White Oaks, Md.

Punch Card Controls for Heat Treating

Shown for the first time at the Metal Show in Detroit, was the "Robotrol, an automatic system for quality control in heat treating", according to its developer, Lindberg Engineering Co., Chicago. Basically, a punch-card system, the job ticket is a standard punch card (much like the familiar IBM type) on which the metallurgical department indicates detailed heat treating instructions. This card travels with the work. When the lot arrives at the furnace to be processed, the operator merely places the punched card in a slot on the control panel. Thus, specifications for all the metallurgical factors required for the job are correctly followed, and when the job is completed the card pro-

vides a record of the treatment. This new system is said to completely eliminate the possibility of human error by the furnace operator.

The first "Robotrol" is scheduled for an installation where it will be employed mainly for carburizing (A.I.S.I. 1118 and 8620) and through hardening (A.I.S.I. 1141) a variety of gears, including spur, helical and herringbone types.

Vacuum Induction Furnaces Are Getting Bigger

A 10,000-lb. capacity vacuum induction unit for melting and casting ingots will be built for Allvac Metals Co. Melting time will be about 3 hr. The unit, built jointly by the F. J. Stokes Corp. and Inductotherm Corp., will have a vertical melting and casting chamber 20 ft. in diameter and 40 ft. high. It will be capable of casting ingots up to 20 ft. long. The vacuum chamber will have a 50-cu.ft. bulk-addition-maker. The pumping system will consist of six 16-in. oil-vapor booster pumps and six mechanical booster pumps.

Missile Chamber Skirt Fabricated by Spin Forging

A missile chamber skirt of unusual size was produced from 0.5 Ti molybdenum alloy. The part (see photo) was spin forged from a 36-in. square and 0.200-in. thick sheet by Universal Cyclops Steel Corp. for North American Aviation. The 0.5 Ti molybdenum alloy was selected for this application to eliminate the need for complex cooling systems and for weight reduction.

This nozzle thrust chamber skirt must withstand 3000° F. and is coated for oxidation protection. 0.5 Ti molybdenum alloy has high strength at elevated temperatures in that range. The part was fabricated hot on a 70-in. spin forging machine. Heat was supplied by oxyacetylene to torches and quartz lamps during the spinning operations.

In the sequence of operations the plate, supplied in the hot rolled stress relieved and descaled condition, was machined to a circular blank. It was drop hammer formed to a dish shape at 1200° F., die temperature being 900° F. The dish was stress relieved in hydrogen at 1950° F. for 1 hr. Then it was spin forged at 900° F., the wall thickness being reduced 32% to 0.136 in. It was again stress

Spin Forged Shape of 0.5 Ti Molybdenum Skirt
Walls Were Reduced From 0.091 to 0.050 In. in Final Operation

relieved in hydrogen at 1950° F. for 1 hr. This was followed by a second spin forging operation at 900° F., with the wall thickness reduced 33% to 0.091 in. This was followed by a third stress relief in hydrogen at 1950° F. for 1 hr. and a third and final spin forging operation. The part was formed to the required length and final wall thickness at 900° F. with the wall thickness being reduced 45% to 0.050 in. The final stress relief was in hydrogen at 1950° F. for 1 hr. followed by flanging of the top by manual hot spinning. The finished dimensions of the thrust chamber skirt are: top O.D., 16.668 in.; bottom O.D., 30.182 in.; height, 23.773 in.

Oxygen Converters Produce 240 Tons of Steel Per Hour

The largest oxygen furnaces built to date are now making steel at the Jones & Laughlin Works in Cleveland. Heats of up to 240 tons are being made in as little as 59 min.

These furnaces are huge. Each weighs 455 tons, including the 141-ton steel shell and a lining of 314 ton of heat-resistant refractories. As for dimensions, they are 27 ft., 10½ in. high and 21 ft., 8½ in. in diameter at the widest point. Furnace mouths are seven feet in diameter. To facilitate rapid charg-

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Technical

NEWS

In Brief

ing, a new type of scrap charger is employed. When in operation, scrap is first loaded into a series of boxlike containers. One of these in turn is placed onto a scrap charger with a specially-designed integral chute that can load the furnace in less than a minute in a single operation.

The oxygen generating plant (built by Air Products, Inc.) contains two units; together, they can produce 534 tons of high-purity (99.5%) oxygen per day. The oxygen plant also contains storage facilities for 815,000 cu. ft. of gaseous oxygen, and for 18 million cu. ft. of liquid oxygen.

For air pollution control, the furnaces are equipped with electrostatic precipitators. Gases are drawn into hoods by four fans (each of which can move more than 325,000 cu. ft. of gases every minute) and sprayed with water to remove the heavier material and lower the temperature (from 3000 to less than 500° F.). The precipitators then remove the fine dust by means of electrical charges which attract the dust particles to metal grids.

These new furnaces will supply steel for a new hot strip mill which, according to J & L engineers, is so fast that it can roll enough steel every 45 minutes to build a mile-wide circle six feet high.

Beryllides—New High-Temperature Materials

A new class of structural materials, beryllide intermetallic compounds, promises to extend maximum service temperatures 40% beyond the range of cobalt and nickel-base superalloys. Made by combining beryllium and a refractory metal such as tantalum, beryllides show an important advantage over the refractory metals in that they are resistant to oxidation up to 3000° F.; they also possess high specific heat and good thermal conductivity for heat sink applications. Although some ceramics have maximum use temperatures higher than these new materials, tantalum beryllides such as $TaBe_{12}$ and Ta_2Be_{17} are ten times as strong (modulus of rupture values of 26,000 to 35,000 psi.) at 2750° F. Brush Beryllium Co. is fabricating small parts – cones, rods, tubing and plates – by vacuum hot pressing of powders, cold pressing and sintering, slip casting, and flame spraying, and sees no reason why the product cannot be scaled up to appreciably larger sizes. Compounds containing other refractory metals such as columbium and zirconium also show promise as high-temperature beryllides.

The beryllides can be considered to possess a combination of the most favorable properties of the superalloys, the refractory metals and the ceramics. In addition, beryllides compare favorably with aluminum in weight. These properties would be desirable for applications in re-entry and hypersonic flight environments.

Continuous Vacuum Furnace Processes Diodes

Vacuum processing has been put on a continuous basis with the start-up of a new conveyor furnace at General Instrument Corp., Newark, N.J. With this unit, (built by C. I. Hayes, Inc., Cranston, R.I.), the plant alloys diodes under controlled conditions. Except for loading and unloading, the entire furnace operates automatically. "Boats" holding the diodes are placed on a conveyor which automatically injects them into a vacuum-lock inlet. From here, the boats travel through the heat zone (maintained at up to 1830° F.), and return to the atmosphere through the vacuum-lock outlet. (Both locks, incidentally, operate much like revolving doors to maintain the vacuum seal. See photo).

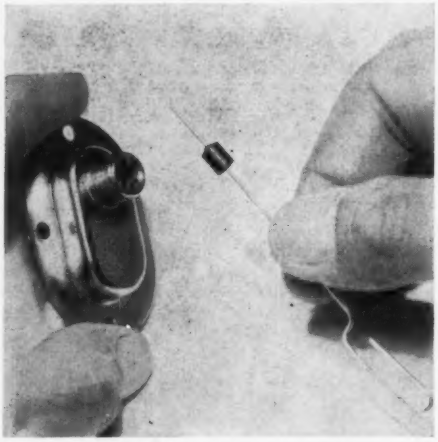
In service, the furnace can attain pressures as low as five microns of mercury, and maintain operating pressures at 50 microns continuously and dependably when under load. As for output, it is

Continuous Vacuum Furnace
Cover Is Removed to Show "Revolving Door" Lock for Vacuum Seal

processing 34 boats per hour, with 300 diodes per boat. At this rate it can process over 80,000 diodes in an 8-hr. shift.

Progress in Nonmetallic Materials

A manufacturer of domestic warm air furnace humidifiers (General Filters, Inc., Novi, Mich.) eliminated water leakage in the humidifier and reduced production scrap nearly 15% by replacing brass valve orifices with ones made of sintered nylon. (See photo.) A mixture of finely divided nylon and graphite was formed into valve seats by a cold-pressing and sintering process. These parts have been in service over three years without leak-



Nylon Valve Seat Has Longer Life
Also, Production Scrap Was Cut 15% by Replacing Brass Valve Seats With Nylon

age. Permanent wear resistance of the sintered nylon prevents any discernible erosion of the valve orifice. There is no problem with water absorption and swelling which could alter the dimensions of the orifice and interfere with proper metering of water.

Sintered nylon valve seats present no scrap or refinishing problems. Accidental dents, nicks and scoring are reduced by the toughness and resilience of the nylon material, which yields slightly under impact without retaining dents.

From Here and There

New magnesium alloys containing 11% or more of lithium are about 20% lighter than magnesium and are ductile, making them suitable possibly for structural parts of missiles and space vehicles. Paul D. Frost, Battelle Memorial Institute, in reporting on these alloys at the recent meeting of the Magnesium Association in New York pointed out that in such applications the critical booster weight-to-payload ratio could be stepped up considerably. Light structural components made from 11% Li magnesium alloy would permit larger, more fully instrumented satellites to be orbited.

• • •

Single crystals of high-purity tungsten (99.9975% W) 10 in. long and 0.22 in. in diameter have been produced by zone melting employing the electron beam principle of heating. Tungsten in the ultrapure single-crystal form is ductile even at -330° F. Tungsten strip, 3 ft. long, ½ in. wide, and 5 mils thick has been cold rolled from a single crystal; wire as fine as 30 mils in diameter has been drawn. The work is being done at the Westinghouse Lamp Div., Bloomfield, N.J.

• • •

Achievement of a 300,000-psi. superbolt elevates steel to a point comparable with titanium in the strength-to-weight ratio. Comparing strength to density, highest strength titanium fasteners to date have a 1,000,000 ratio, while the bolts referred to here are rated at 1,100,000. These fasteners, produced by Standard Pressed Steel Co., are tension and shear bolts made from Vascojet-M-A alloy. Availability of these parts can effect a 10 to 20% reduction in the weight of aircraft landing-gear assemblies and would make possible a propeller-driven aircraft speed above Mach 2.

International Progress and Forecast Issue Next Month

The January issue of *Metal Progress*, our Tenth International issue, will feature articles on progress in materials and process engineering in Australia, Belgium, Britain, Soviet Union, Canada, France, India, Italy, Japan, Netherlands, East Germany, and West Germany. The editors will also present Technology Forecast, a special report on what technical management can look for in the year ahead.

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METAL PROGRESS

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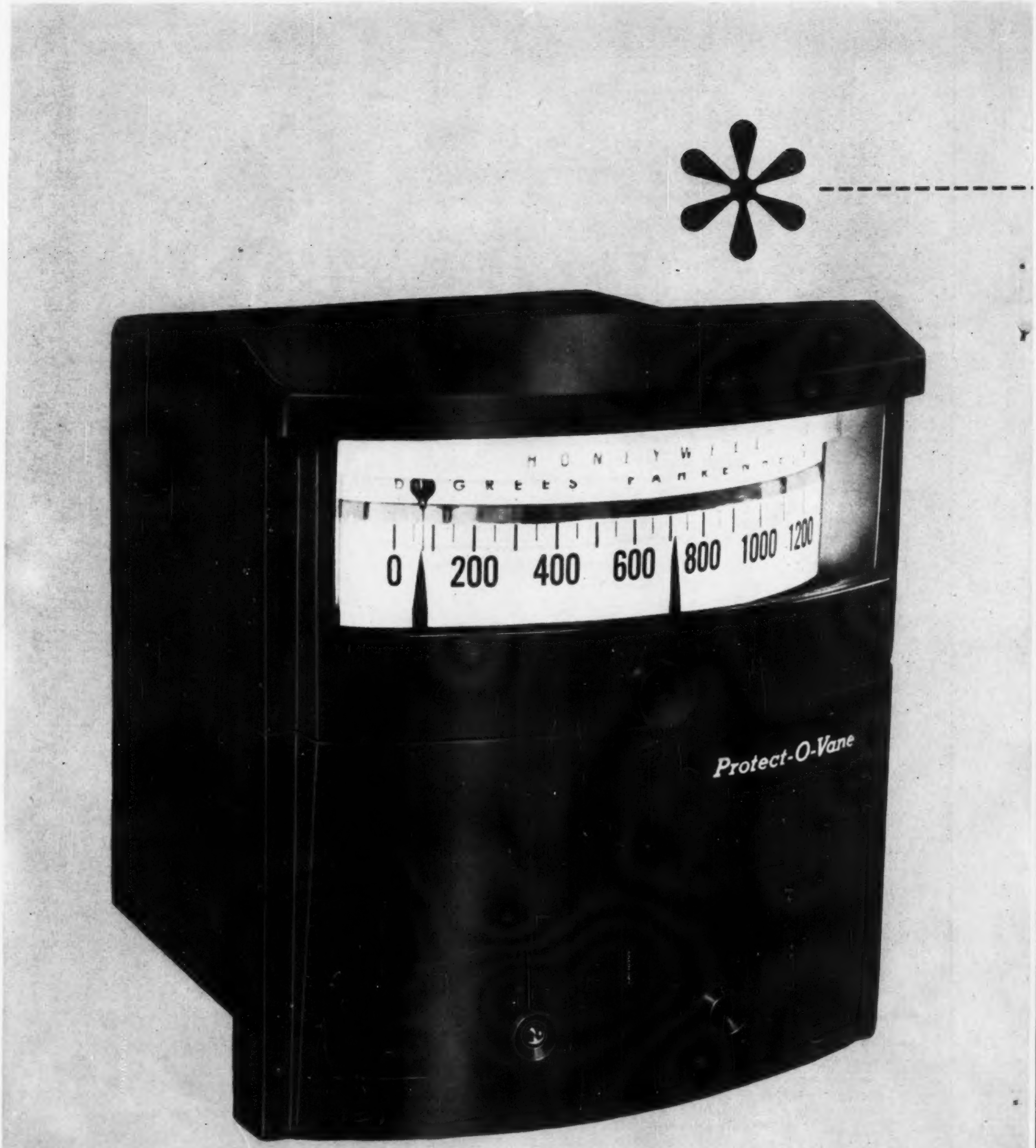
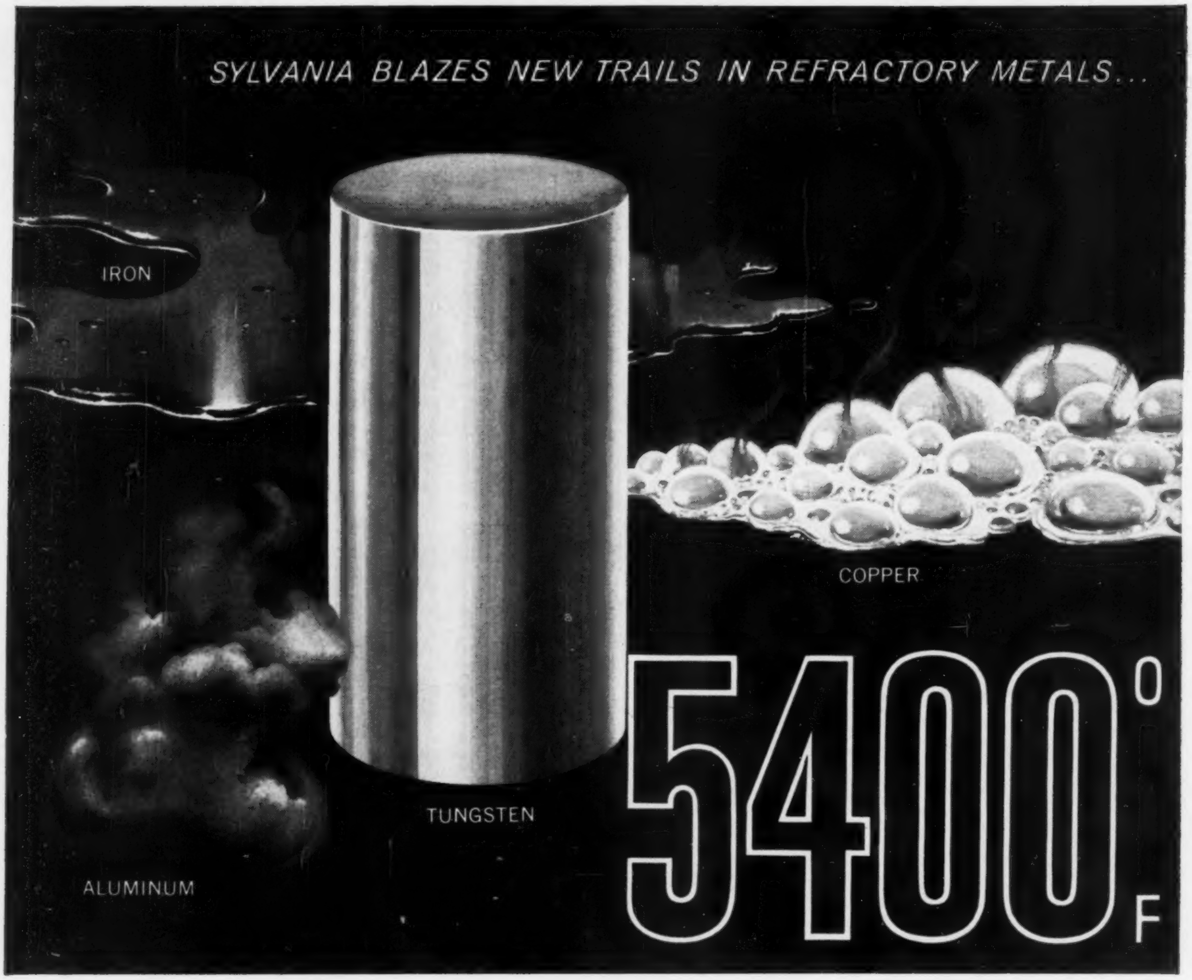


New Honeywell Series 10/20 Millivoltmeters give you an easier-reading scale, and all the latest features for indicating, controlling and safety cut-off.



DEFENSE-BORN SKILLS

... bring you high temperature metals shaped to solve your future needs!

At 5400° F. iron runs like water. Copper boils. Aluminum vaporizes. But tungsten keeps its strength.

To help you use this strength—and heat resistance—Sylvania now offers you the benefits of its unique versatility. It can produce tungsten and molybdenum for such different applications as billets and ingots for you to forge, as electrodes for your arc casting, as blanks for you to machine, or as blanks already machined to the most exact tolerances.

Sylvania can accomplish all this because it can now capitalize on developmental work done for the military—and bring you solutions to many long-standing riddles.

Have you given serious thought to refractory metals? The same properties that solve the problems of throat inserts for rockets and missiles can pay you dividends in gas turbines, jet engines, extruded airframe members, heat exchanger parts, piercing points and in many other ways.

Want full details? Or experienced help in proving out your special ideas? Write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pa.

SYLVANIA

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NATIONAL CARBON COMPANY'S

DECEMBER, 1961
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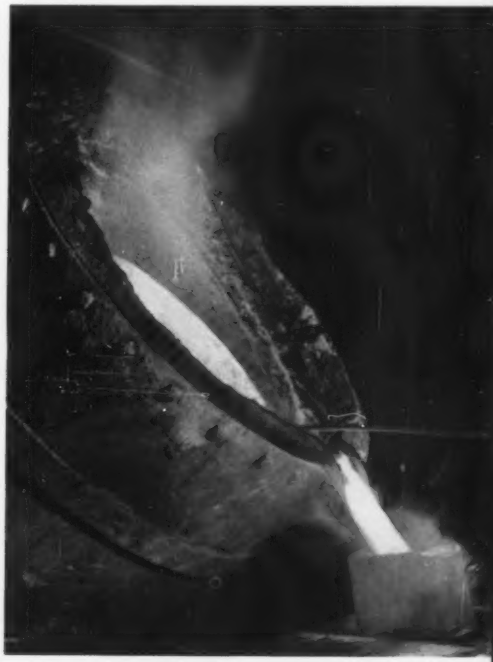
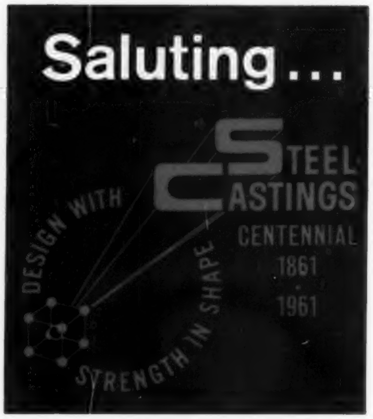
CARBON AND GRAPHITE NEWS



Saluting...

Progressive Foundries move ahead with Electric Arc Furnaces

Progressive Foun With Electric



A century ago the steel casting industry in the United States was born in Buffalo, New York. A small company known as the Buffalo Malleable Iron Works poured the first crucible steel castings for the industry's first and still largest customer—the railroads.

Although its history of achievement reaches to the days before the Civil War, the steel foundry industry is still in its youth . . . still growing . . . still proving exciting and challenging to the men who have made it—and keep it—a vital segment of our highly mechanized economy.

From 1861 to 1883 the art of steel casting in this country made little progress. In the latter year, less than 1,700 tons were produced. In 1885, six foundries were in operation, producing 10,000 tons of castings yearly. At the beginning of the twentieth century the number of foundries had increased to 85, with an annual output of 177,000 tons.

Today, the steel casting industry is comprised of approximately 240 commercial foundries, employing more than 50,000 persons, and capable of producing at the rate of nearly 2,500,000 tons per year.

Perhaps the most important factor in the mushroom growth of the steel casting industry was the introduction of the electric arc furnace. This giant step came in 1910, when an experimental 300-pound-capacity electric furnace in the Sharon plant of National Castings Company was used to melt the first foundry steel produced in a furnace of this type.

In this history-making year for the steel casting industry in the United States, National Carbon Company, Division of Union Carbide Corporation, proudly salutes the industry's first one hundred years of progress, the observance of which is being directed by the Steel Founders' Society of America. National Carbon Company, for many of its 75 years of business life, has been privileged to contribute to the growth of the foundry industry—through constantly developing new and better carbon and graphite products.

As the foundry industry moves into its second century, National Carbon pledges its skills and resources to help it achieve higher and higher levels of efficiency in furnace output and plant operations.

Data on the early history of the steel casting industry provided through the courtesy of Wilson H. Moriarty, First Vice-President, National Castings Company, and 1960-1961 President of the Steel Founders' Society of America.

dries Move Ahead

Arc Furnaces

The making of steel entered the era of "push-button," precision-controlled production half a century ago when the electric furnace moved into the scene. Since then it has opened many new ideas, concepts, and methods . . . new horizons in progress . . . for large and small foundries.

Electric melting has made it possible for foundries to produce metals in variety to meet specific needs . . . has raised the control of metal analysis to an exact science . . . has provided melting flexibility that can be speedily adjusted to coincide with molding capacity.

Recently, the editor visited six foundries in five states from coast to coast. In-plant studies made at each of these widely separated locations clearly indicate the importance of electric arc furnaces to the forward-moving growth pattern of the steel casting industry.

The physical limitations of this issue prevent coverage of all the foundries throughout the country using electric arc furnaces today. The following six stories are typical of operations in foundry after foundry that make up this progressive industry.

FIRST TO USE THE ELECTRIC FURNACE IN THE STEEL FOUNDRY INDUSTRY

National Castings Company
Cleveland, Ohio
Sharon, Pennsylvania, Works

National Castings Company began its corporate history in 1868. This year, the name of the organization was changed from National Malleable and Steel Castings Company to National Castings Company to reflect more accurately the nature of its business.

A Pioneer in Electric Melting

In 1910, Sharon installed an experimental electric furnace with a capacity of about 300 pounds. In the years 1912 and 1913 two 11-ft. shell electric furnaces were installed. These units were used successfully for a number of years. They are still in existence, and with proper renovation could be brought back to the production line. Although lacking in the refinements of today's multi-ton electrics, these early furnaces served to prove to management that the trend to future foundry practices would necessitate the speed, flexibility, and precision metal control inherent in the electric arc furnace.

Five New Electrics Installed

In 1951, the last of Sharon's open hearths was replaced by its fifth new electric arc furnace. All five of these units are acid-lined, ten-ton capacity, top-charged furnaces. Each utilizes a 3000 KVA transformer and operates with secondary voltages of 245 on A tap, 190 on B tap, and 110 on C tap.

During 1960, and the first half of 1961, heat times averaged 2 hours and 17 minutes, tap to tap. Recently, oxygen has been used during refining to drop carbon content of the heat from 0.38 to an average of 0.17 at the time of tap.

"These electric furnaces are important, but what we do with them is more important," says Robert Everett, Plant Manager, Sharon Works. "We are pleased with our electric furnaces, because we find them to be the most flexible and fastest steel-producing tool for a foundry of our size. They provide substantial cost-saving advantages over other types of melting equipment."

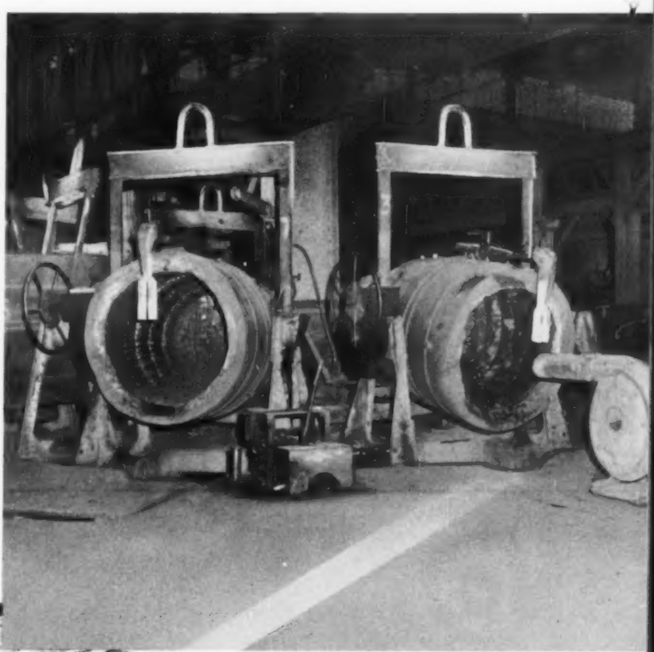
Complete Quality Control

Sharon Works initiated an extensive quality control program 15 years ago. Since then this program has been expanded to cover the charting of approximately 100 separate factors affecting foundry practices. Included are factors such as: control of chemical analyses of heats, physical properties of castings produced, power consumption per ton of steel, heat times, casting dimensions and weights, and sand control.

For example, Sharon has electrode consumption data compiled on a day-by-day basis covering the ten-year period from 1950 to 1960. As shown by the table, electrode consumption per ton of steel has dropped from a high of 11 plus pounds per ton in 1952 to a low of 8½ plus pounds per ton in 1960. Some of the major reasons for lowering of electrode consumption are: general improvement of electrode quality, better maintenance of electrode holders, cleaner joining techniques, and improved over-all efficiency throughout the melting department.

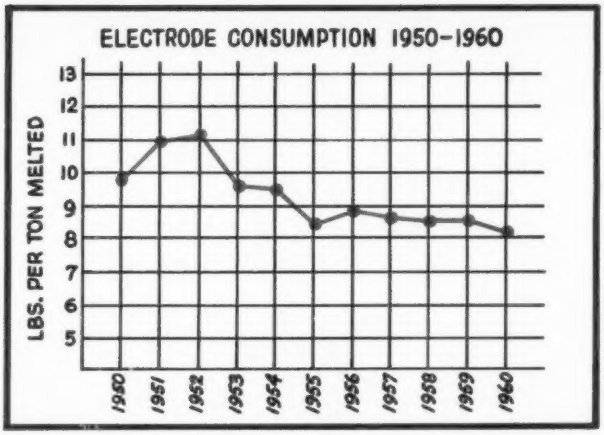
Also, chemical analyses on heats are held to exacting tolerances and recorded daily on charts in the quality control room. Data covering carbon, manganese, silicon, and sulfur are meticulously plotted for each heat and held to strict limitations. The slightest deviation from normal melting practices is spotted immediately and promptly corrected.

In addition to the across-the-board quality control program maintained by Sharon, various inspection tools are used to minimize casting flaws. One such tool is a million-volt x-ray machine with a maximum depth penetration of five inches. Magnetic particle inspection exposes defects up to ¼-inch below the surface.



Unique merry-go-round installation makes for efficient and orderly preparation of ladles.

Oxygen is used at time of tap to drop carbon content of the heat.



Electrode consumption data compiled on a day-by-day basis covering a ten-year period.

As a result of its highly coordinated melting efficiency, mechanized foundry practices, and continuing precision quality control, Sharon Works of National Castings Company in 1960 achieved the lowest ratio in its history of man-hours per ton of castings produced.

OXYGEN-GAS BURNERS INCREASE ELECTRIC FURNACE PRODUCTION

Oklahoma Steel Castings Company
Tulsa, Oklahoma

Since its establishment in 1922, Oklahoma Steel Castings Company has steadily grown in size. This firm manufactures an extensive line of quality products for the aeronautical, agricultural, automotive, railroad, pipeline, mining, refining, steel, power, and bridge and highway construction industries.

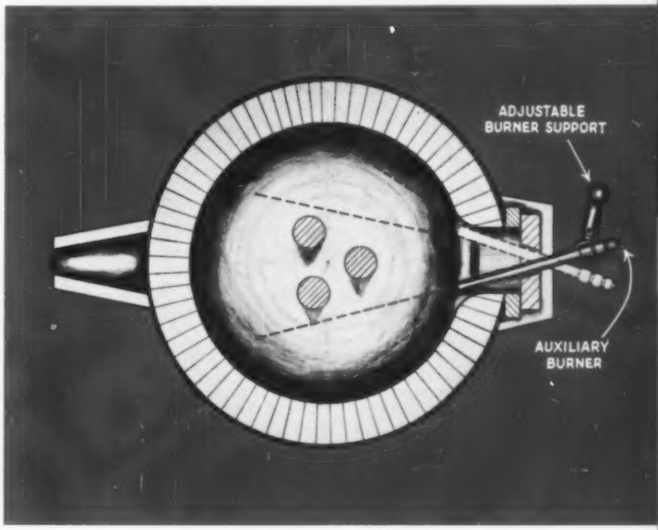
Electric Furnace Production Boosted

In June, 1959, Oklahoma Steel initiated a study of the advantages in using oxygen fuel gas burners through the door of a 4-ton, acid-lined, top-charge electric furnace during melt-down. First trials indicated that this technique would provide an economical increase in production whenever required by increased molding demand. Analysis of test results proved conclusively that output could be expanded without affecting product quality. This was the benefit Oklahoma Steel was searching for in its Tulsa foundry.

Burner Employed Full Time

Within a short time after the testing period, an oxygen-gas burner was employed on all heats except the first heat of the day. This plan was continued until the full economy of the operation could be determined. After a brief period the operators' techniques improved with practice and reflected even shorter heat cycles than those experienced during the initial tryouts. Here are some of the advantages Oklahoma Steel realized from the application of the burner to their melting practices:

SHORTER HEAT CYCLES: Production increased from 113.75 pounds per minute to 131.17 pounds per minute, a gain of 17.42 pounds, or 15.3 per cent. The decrease in melt-down time resulted from added heat, elimination of scrap bridges, and a more stable arc. Cold spots in the furnace can be heated with the burner, and light scrap can be cut from the sidewalls. A principal advantage at Oklahoma Steel is that melting capacity can be increased without any capital expenditure.



Typical door burner installation for furnaces having a capacity under ten tons.

LOWER REFRACTORY COSTS: Refractory costs were reduced by 15 per cent. KWH consumption was decreased by 57 KWH per ton. Electrode consumption remained normal.

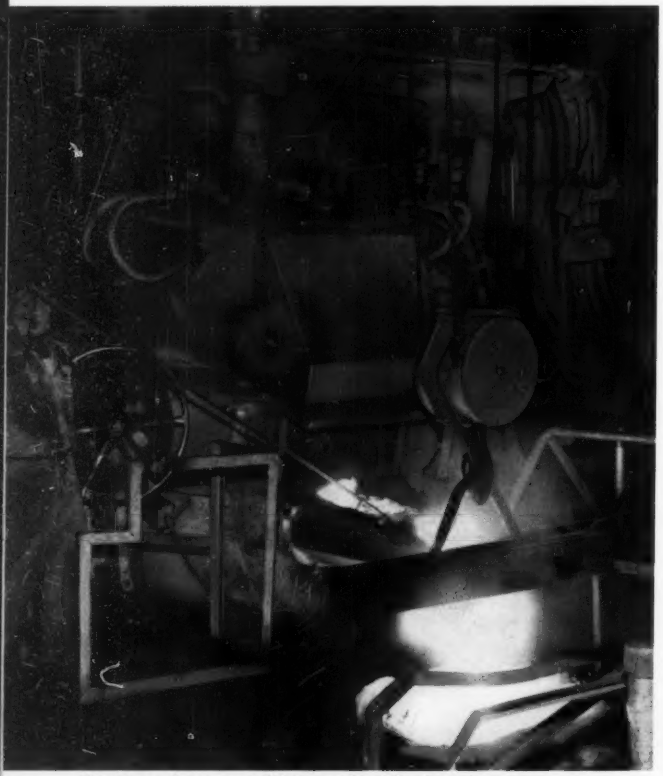
Using the oxygen-natural gas burner through furnace door.

LOWER PLANT COSTS: An average saving of 10 man-hours per ton of steel was reflected in plant costs. Molding time per ton of steel was lowered and overtime was eliminated in many instances.

OXYGEN CONSUMPTION: Average oxygen consumption was 600 cubic feet per ton, while average natural gas consumption was 400 cubic feet per ton.

The Tempo of The Plant

Oklahoma Steel management states that, "these modern melting facilities—the electric furnace teamed with oxygen-natural gas burners—are the backbone of Oklahoma Steel's foundry operations. They permit melting of a wide range of analyses on short order, and allow economical adjustment of melting capacity to molding capacity. The flexibility of the equipment was effectively demonstrated when it recently produced 25 heats from one furnace in a 24-hour day."



Tapping a furnace at Oklahoma Steel Castings Company.

An interesting factor concerning the installation of the oxygen-gas burner was the matter of plant safety. Despite the fact that Oklahoma Steel's personnel had to adjust to new techniques of operation, the company's unusual and impressive safety record was not blemished during the training period. This record—over 1,000,000 man-hours without a lost-time accident—is the best score reported to the Steel Founders' Society of America for any foundry in the country.

1% CARBON STEEL ROUND-THE-CLOCK WITH ELECTRIC FURNACES

American Brake Shoe Company
Calera, Alabama

To produce "Southern" Cast Steel Wheels in volume—and to obtain high quality at low cost—American Brake Shoe installed electric furnaces at their Railroad Products Division plant in Calera, Alabama.

This plant closely approaches the ideal straight-line, continuous-flow foundry principles. All possible operations are mechanized. Power-operated equipment and push-button control have made possible an increase in production of 1 per cent carbon cast steel wheels from 37 per day in 1954 to 540 wheels per day in 1961.

Electrics Play a Vital Role

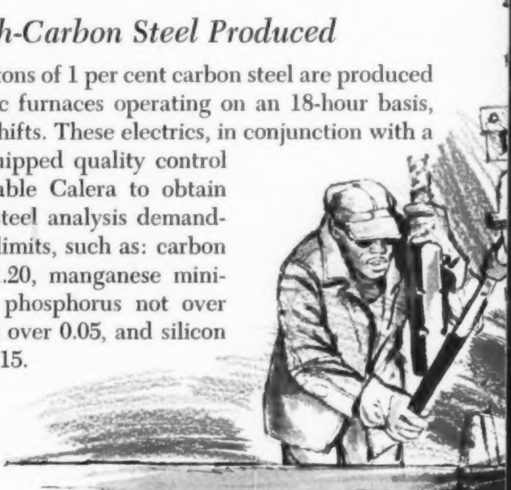
Melting capacity at Calera consists of four 9-foot, top-charge, basic electrics, utilizing transformers rated at 3500 to 4000 KVA. Three of these furnaces operate around-the-clock, with heat times averaging 1 hour and 45 minutes per furnace, tap to tap. A fourth furnace is held on stand-by for use during maintenance and relining periods.

Electric arc furnaces play a vital role at Calera by permitting the production of steel which must be held to analysis of pinpoint accuracy. These furnaces are readily adjustable to meet the requirements of modern, high-speed, foundry conditions.

"Electric arc furnaces," in the opinion of Steve Davis, Plant Manager at Calera, "are the only melting tool that can offer us maximum flexibility of production and still maintain on-the-nose metal analysis. They turn out steel according to demand and can be operated on any number of shifts and for any number of days per week."

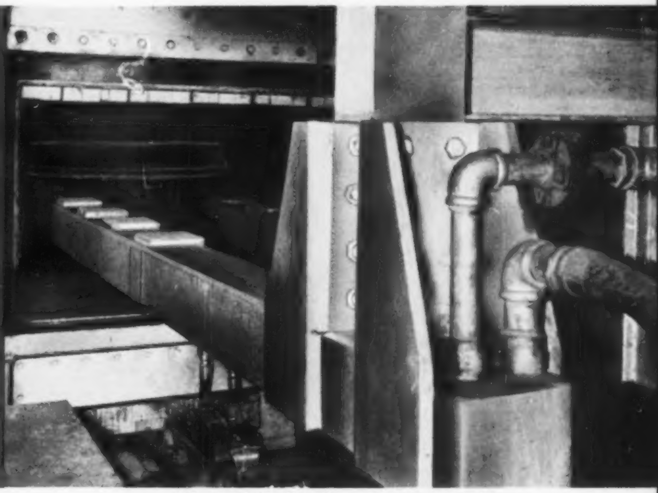
High-Carbon Steel Produced

More than 250 tons of 1 per cent carbon steel are produced in three electric furnaces operating on an 18-hour basis, or two 9-hour shifts. These electrics, in conjunction with a completely equipped quality control laboratory, enable Calera to obtain uniformity of steel analysis demanding very close limits, such as: carbon from 0.95 to 1.20, manganese minimum of 0.50, phosphorus not over 0.05, sulfur not over 0.05, and silicon not less than 0.15.



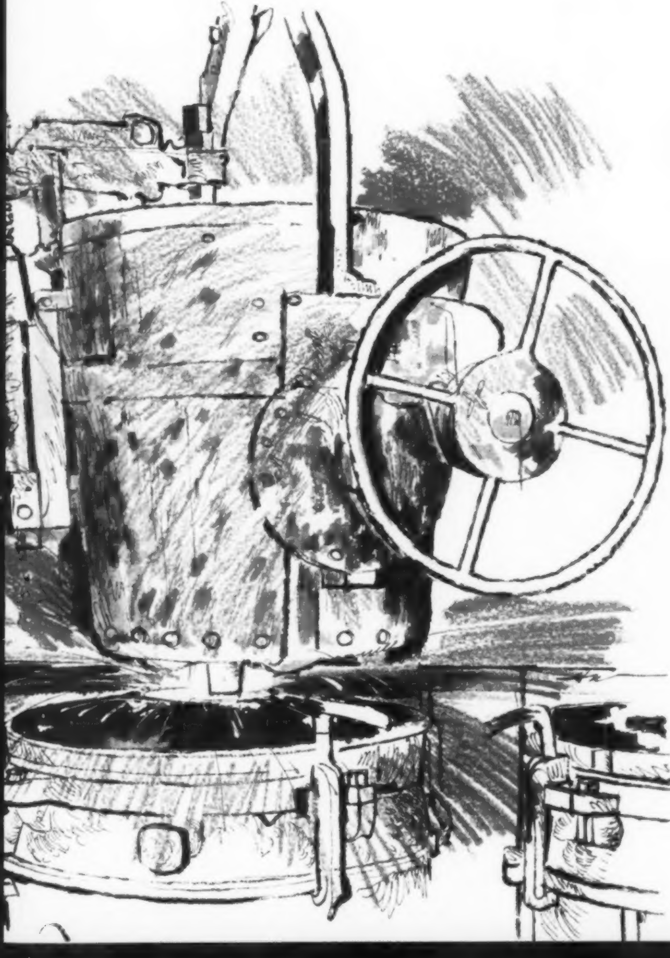
Teeming from bottom-pour ladle into wheel molds. Ladle has capacity to pour four wheels.

Melt floor at Calera showing line-up of four 9-foot, top-charge, basic electrics.



New heat-treating furnace with capacity to handle 600 wheels per 24-hour day.

Steel is tapped from the electrics into a teapot ladle where alloying additions are made, preferably, at a temperature of 3,000°F. This ladle is placed on the pouring stand where sufficient metal to pour four wheels is transferred to a bottom-pour ladle and teemed into the wheel molds. The heat of the metal is checked on the first, third, and last pour to assure that the temperature does not drop below 2,770°F.



Plant Capacity Expanded

In July, 1961, the Calera plant completed a major expansion program. Heat-treating facilities were upgraded to handle a maximum of 600 wheels per 24-hour day. Other areas of the foundry were modernized to permit utilization of approximately 25 per cent more electric furnace steel.

In the near future a 670,000 s.c.f. at atmospheric-pressure liquid oxygen storage unit will be built at Calera. Oxygen is presently being used to reduce carbon during refining. Experiments have been conducted using oxygen door lances to speed heat times during melt-down. "These experiments," according to E. A. 'Red' Bacher, melting foreman, "have shown us that we can reduce melt time as much as from fifteen to twenty minutes per heat."

In 1962, American Brake Shoe plans to expand its total steel casting production by converting its cast iron wheel plants in St. Louis, Missouri, and Toledo, Ohio, to cast steel wheel plants similar to the Calera operation. A top-charge electric furnace with a 10-ft. shell diameter will be installed in both foundries to provide the same flexibility and dependability of melting operations long associated with Calera.

ELECTRICS REPLACE OPEN HEARTHS IN MODERNIZATION PROGRAM

Birdsboro Corporation
Birdsboro, Pennsylvania

Birdsboro Corporation, dating back to 1740, began as an iron forge in the municipality of Birdsboro, Pa.

Conversion to Electrics

Installation of three electric furnaces—key elements in a recent modernization and expansion program—gives Birds-

boro outstanding metal production flexibility. The foundry can melt up to 300 tons of high quality steel a day. Where production was limited previously to carbon and low-alloy steels, the range of products that can be cast now includes stainless and high-alloy steels for use in high-pressure, high-temperature, and corrosion-resistant applications.

Before the full conversion to electric furnace melting the foundry could melt nothing smaller than an 8-ton heat. Today, it can produce a minimum melt of 4 tons, which means that smaller orders can be handled, heats scheduled more efficiently, and deliveries improved.

New electric furnace having a shell diameter of 13½ ft. and a melting rate of 7 tons per hour.

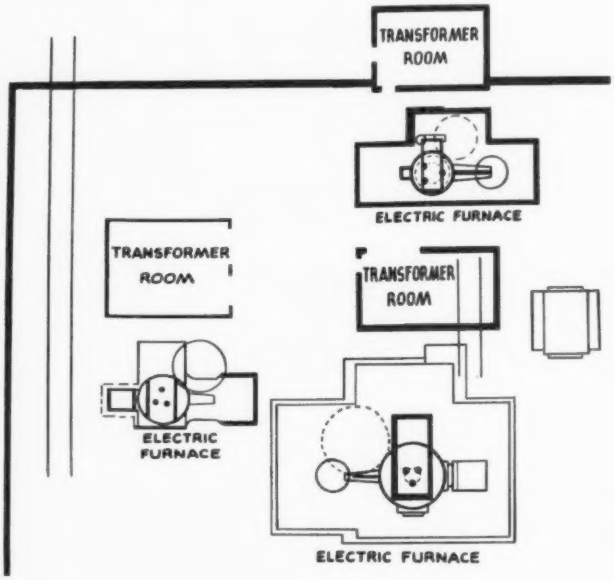
Increased Melting Capacity

Birdsboro's first electric furnace has been in continuous operation since January, 1955. This unit, with an 11-ft. shell diameter, handles an average heat of 15 tons at a melting rate of 5 tons per hour.

Both of the new furnaces, installed late in 1960, slightly overlap the melting range of the older furnace but provide smaller and larger capacities. The smaller furnace has an 8-ft. shell diameter and handles an average heat of 5 tons at a melting rate of about 2 tons per hour. The larger of the new furnaces has a 13½-ft. shell diameter and a melting rate of 7 tons per hour.

With the three electric furnaces in operation, Birdsboro can cast parts ranging in size from 50 to 80,000 lbs. The foundry has a 50-ton crane capacity and can produce castings weighing as much as 100,000 lbs., depending on design and linear requirements.

Steel chemistry is vastly improved by basic electric melting practices. Sulfur and phosphorus content in the heat is consistently below 0.020%. Carbon is removed from the melt with gaseous oxygen to improve quality and speed up refining. In all, the basic electric furnace is a faster melting tool and provides steel of a much higher, consistent quality than the earlier acid open hearth furnaces.



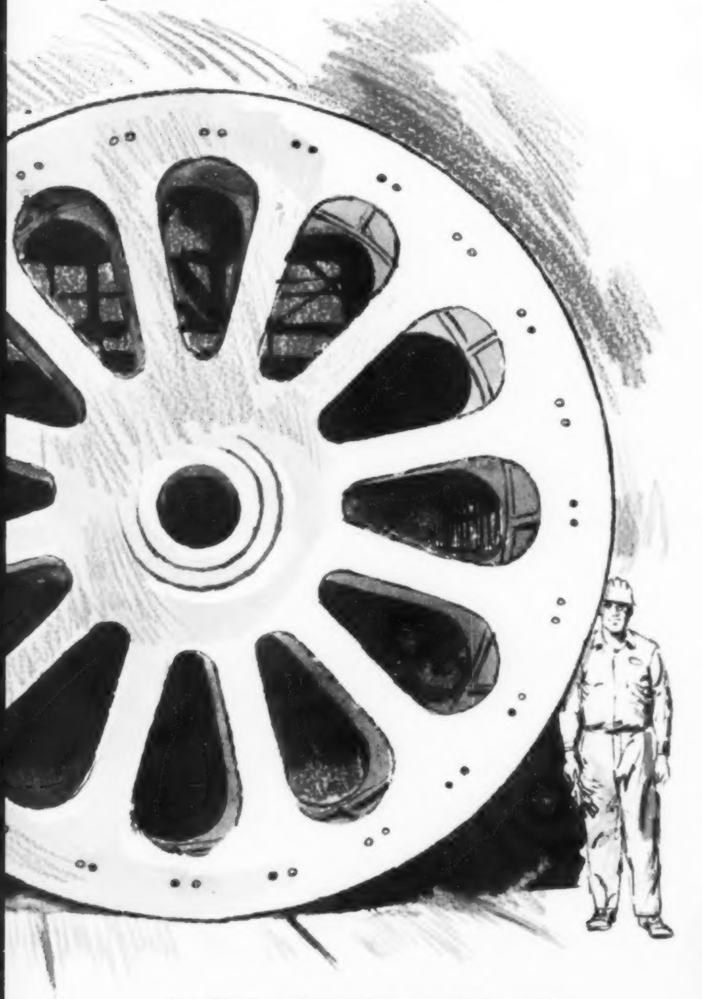
Melt floor area of modernized and expanded Birdsboro foundry.

According to Birdsboro President G. Clymer Brooke, foundries will have to produce quality steel castings if they are to remain competitive. The demand and need for electric steel castings is rising rapidly with no decline in prospect, he points out. High-alloy and stainless steel castings of extra high quality are needed for many modern applications where nothing less than the best will do the job.

"I would estimate that 25% of our current casting tonnage is business we have only because we are equipped with electric furnaces," Mr. Brooke observed. "There are many jobs on which we could not even quote if we did not have these units."

Advantages of Electrics

In a detailed study comparing costs of basic electric melting with acid open hearth melting over a five-year period, Birdsboro found that both the conversion cost and total cost per ton were progressively less for electric furnace operations.



A 53,540 lb. carbon steel sheave wheel measuring 15 ft. $1\frac{3}{4}$ inches cast by Birdsboro Corporation.

The recent installation of the second and third electric arc furnaces has completely eliminated three open hearth furnaces—two of 30-ton capacity and one of 20 tons.

Electrode consumption with the electrics has been good —9½ lbs. of graphite per ton of steel produced. When the electric furnaces are not in full production, the available capacity can be devoted to casting ingots. Production is more flexible, sales possibilities increased, and casting quality improved.

OVER 100 ALLOY STEELS PRODUCED WITH VERSATILE ELECTRICS

Esco Corporation
Portland, Oregon

Esco Corporation started in the foundy industry in 1913 under its original name of Electric Steel Foundry Company.

Today, Esco is a producer of a wide variety of alloy and stainless steel castings and other product lines for a multitude of industries.

In this modern foundry, three types of casting facilities are available: green and dry sand molding, shell molding, and centrifugal molding.

The numerous fields it serves are handled by seven basic divisions: Casting Sales, Construction Equipment, Logging, Sawmill, Crushing Equipment, Process Equipment, and Stainless Cast Specialties.

Esco's Electric Capacity

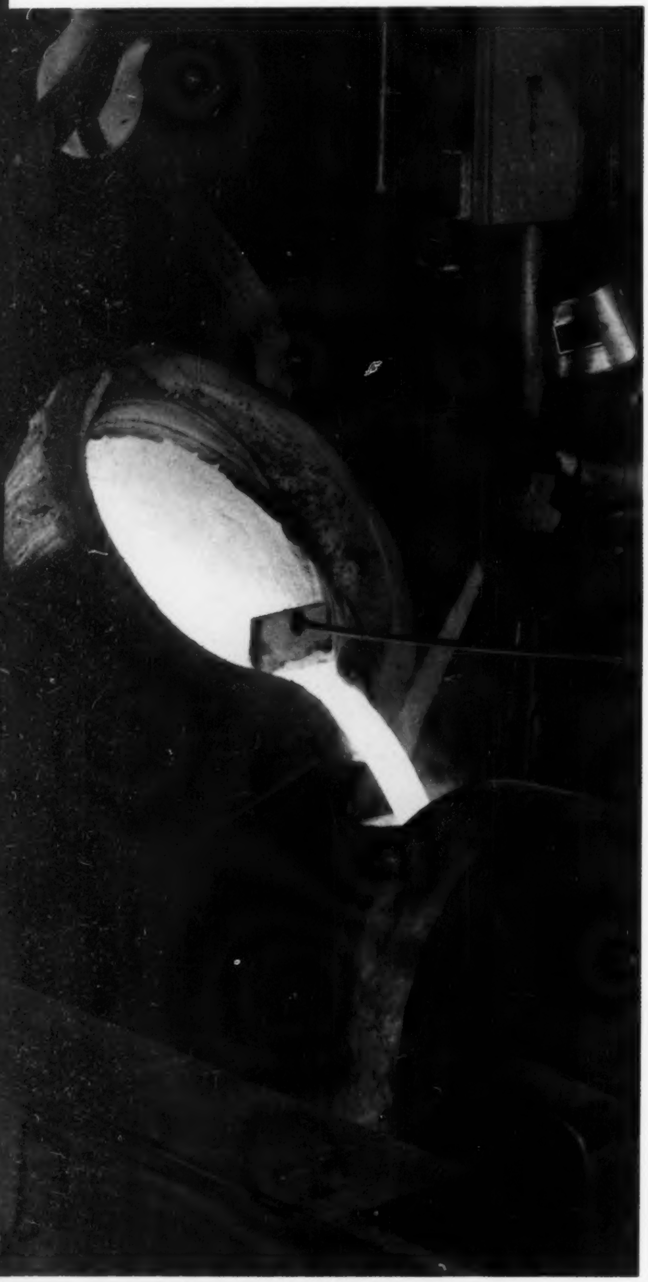
From its early installation of an electric furnace nearly half-a-century ago—when electric melting was a new and revolutionary process—Esco's melt floor has been modernized and expanded over the years to accommodate five basic-lined, top-charge electrics. More than 100 alloy analyses are produced in two 1-ton, two 3-ton, and one 4-ton furnaces. These units are powered by transformers ranging in size up to 3125 KVA.

"Considering the quantity and diversity of alloys we melt, and the quality of our products—plus a finished casting range from a few ounces to 20,000 pounds—no other melting equipment can match the exacting control and the flexibility of operations available with electric furnaces," according to L. E. Fink, Esco's Supervising Metallurgist-Operations.

Tapping an electric furnace at the Esco Foundry in Portland, Oregon.

Melting Practice

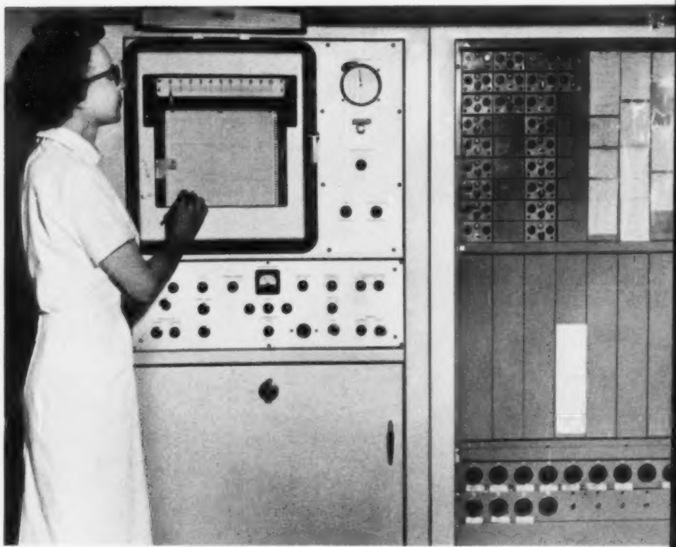
A typical heat cycle in an Esco electric furnace runs as follows: charge to melt-down, approximately 55 minutes; oxygen blow and refining time, roughly 25 minutes; tap and recharge time, an average of 5 minutes. One hour and 15 minutes is the average heat time for all furnaces, tap to tap. Alloy additives are made during refining and deoxidizers are introduced in the ladle.



Pouring molten metal from the large transfer ladle into the pouring cup of a centrifugal casting machine.

How Quality is Assured

Esco has joined the steel casting industry in the adoption of every applicable and successful method of analysis and testing, to assure products that meet the most stringent demands of customer industries. To achieve this goal, Esco utilizes magnetic particle testing, fluorescent penetrant inspection, spectroscopy and tensile and pressure testing methods. In addition, this foundry has recently installed its own Betatron, a 24-million electron volt X-ray machine, which is used to "see through" 2-inch to 20-inch metal sections in a matter of minutes.



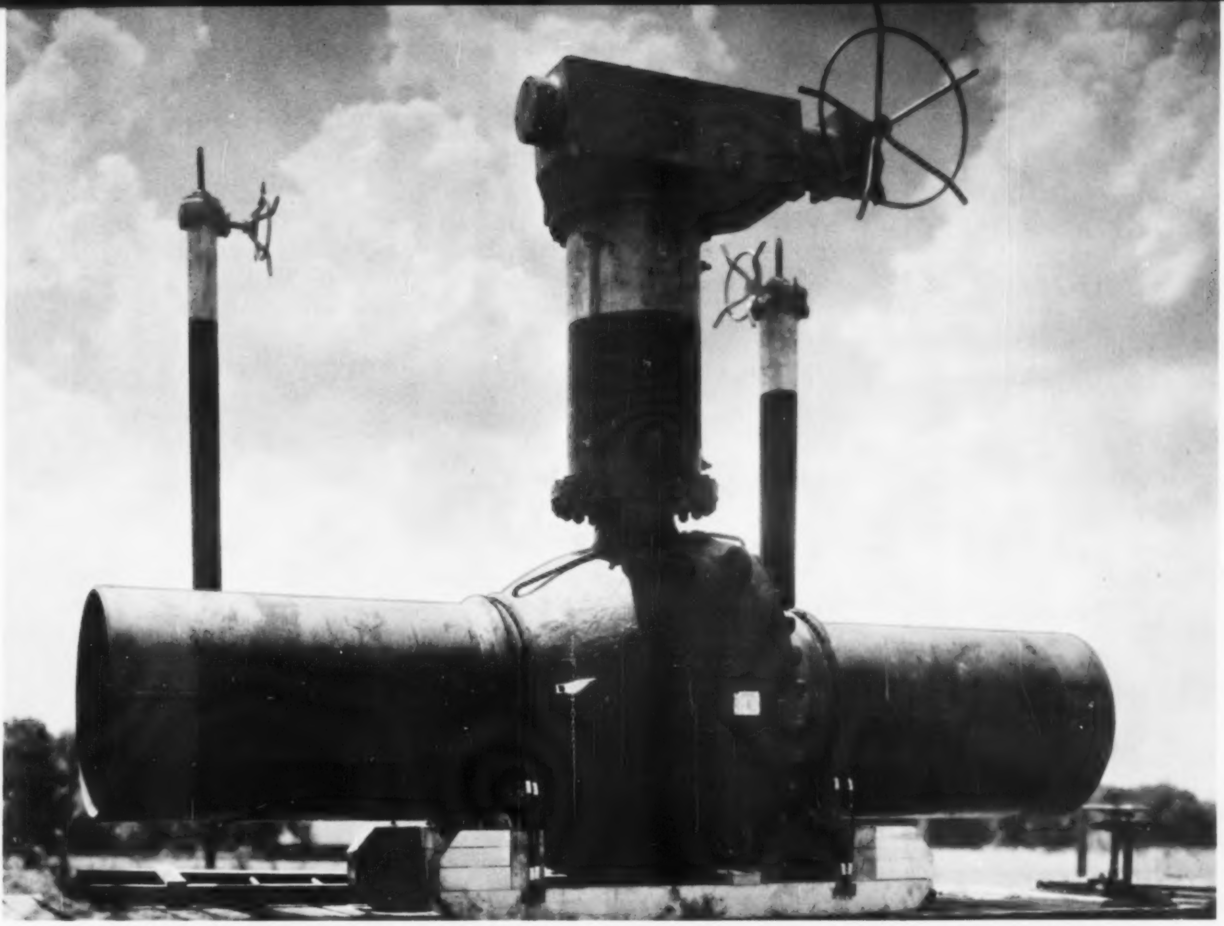
Direct Reading Spectrograph gives a rapid chemical analysis before and after pouring.

Through these up-to-the-minute techniques in melting, casting, and testing, Esco Corporation has found the way to continually multiply the quantity and quality of its alloy steel castings.

RANGE OF FURNACE SIZES AIDS PRODUCTION SCHEDULING

The LFM Manufacturing Company, Inc.
Atchison, Kansas
Subsidiary of
Rockwell Manufacturing Co.
Pittsburgh, Pa.

LFM was founded in 1872. In 1956 the company merged with Rockwell Manufacturing Company and changed its name to The LFM Manufacturing Company, Inc.—a change that only made official a designation by which the firm had been widely known for many years.



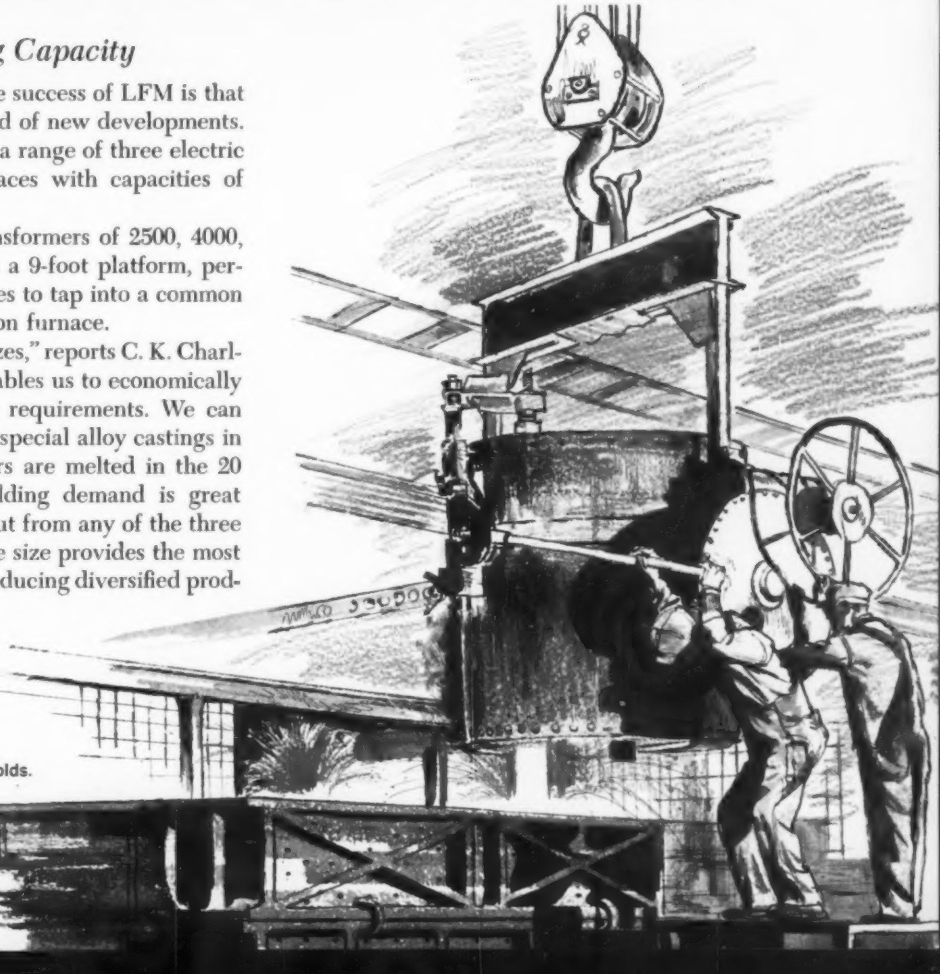
A 36" Rockwell Hypresphere cast steel valve with extended Rockwell valve actuator ready for shipment from the LFM plant.

Range of Melting Capacity

One of the primary reasons for the success of LFM is that it has always been in the vanguard of new developments. For example, the foundry utilizes a range of three electric arc, basic-lined, top-charge furnaces with capacities of 7½, 20, and 35 tons.

These furnaces, employing transformers of 2500, 4000, and 7500 KVA, are positioned on a 9-foot platform, permitting the 7½ and 20-ton furnaces to tap into a common pit. A separate pit serves the 35-ton furnace.

"Our range of electric furnace sizes," reports C. K. Charlton, Works Manager at LFM, "enables us to economically gear our production to customer requirements. We can efficiently handle small orders for special alloy castings in the 7½-ton furnace. Larger orders are melted in the 20 and 35-ton units and if the molding demand is great enough, we can combine the output from any of the three furnaces. This flexibility of furnace size provides the most practical and efficient means of producing diversified products of a wide range of steels."



Teeming from a bottom-pour ladle into molds.

View of furnace floor at LFM showing range of electrics with capacities of 7½, 20 and 35-tons.

Melting Practices at LFM

A typical operating cycle on any one of the furnaces would consist of a 2 or 2 hour and 15 minutes melt-down and oxidation period followed by 30 to 45 minutes "finishing" time. The oxidation is accomplished by the use of an oxygen lance through the door. Chemistry of the melt is checked by spectroscopy three times during the heat. Silicon and aluminum are added in the ladle.

Tap to tap heat times on the three furnaces average 3 hours, while electrode consumption averages 10.8 lbs/ton of steel produced in all furnaces.

Approximately 75 per cent of the metal cast at LFM is carbon steel produced to an analysis specification of 0.65-0.80 Mn, 0.35-0.50 Si, 0.20-0.26 C, 0.05 max P, and 0.05 max S. The alloy steels poured include nickel, chromium-molybdenum, manganese-molybdenum, and nickel-vanadium.

Facilities Recently Expanded

A few years ago, LFM invested approximately $3,000,000 in the expansion of its foundry facilities. The foundry working area was increased from 200,000 to 300,000 square feet and production capacity was raised from 2000 to 3000 tons of finished castings per month.

This program included new buildings for melting and scrap storage, a new 35-ton furnace and accessory equipment, heat-treating facilities, molding machines, cranes, conveyors, and an enlarged sand reclamation and distribution system.

Today, with flexible electric furnaces, plus modern casting and machine shop facilities, LFM produces a broad line of quality castings that range in weight from 100 to 35,000 pounds. The foundry is capable of shipping more than 3000 tons of steel per month, making it one of the largest electric steel foundries under one roof.

Summary

If the technical advances and operating efficiency encountered in the six foundries visited by the editor are characteristic of the nation's other commercial steel foundries, then there is no doubt that this great industry is destined to establish new records in progress during the Space-Age Sixties!

Growth of the industry is constantly being sparked by a never-ending stream of new ideas in foundry practice . . . melting equipment is becoming increasingly more productive . . . better and more reliable methods of analysis and testing are helping to upgrade quality and expand the quantity of steel castings produced today.

No small part of the credit for the forward surge of America's steel casting industry in recent decades is shared by the electric arc furnace. Since its first use by the industry in 1910, this precise melting equipment has offered progressive foundries a dependable means of controlling the metal they produce. It also has enabled them to employ this production to meet exacting foundry schedules.

In foundry after foundry—across the country—new melting techniques are continually being brought into play. Oxygen, as one outstanding example, is being utilized today in some foundries to produce even higher electric furnace efficiencies, with resultant lower operating costs.

In looking across the long and successful history of the steel casting industry, it is predicted that our country's steel foundries—with the assistance of modern electric arc furnaces—will continue to enhance their productiveness and value to their customers at an ever-increasing rate.

TOCCO
Induction Heating Anneals Pipe Welds ...In the Welding Line

Page Hersey Tubes Ltd., Toronto, Ontario, is one of several progressive manufacturers using Tocco induction heating to continuously anneal welds in electric seam-welded 4" diameter and larger pipe to improve ductility and toughness.

The Tocco engineered and built post-weld stations are installed in the line following the welding station. Special Tocco developed inductors, powered by two Tocco high frequency generators, heat the weld affected area on pipe up to 8" diameter ⅜" wall to 1700°F at mill speeds. Annealing is accomplished with no extra handling of the pipe and with metallurgical results at the weld area not possible by any other method. The cost is only a fraction of what it would be if the entire pipe were heated in a furnace.

This is typical of the scope and ability of Tocco's engineering staff to solve metal heating problems with induction heating. If your manufacturing operations require heating metal for forging, heat treating, melting, brazing or soldering, it will pay you to check with Tocco for the latest and most effective methods for increasing production and cutting costs.

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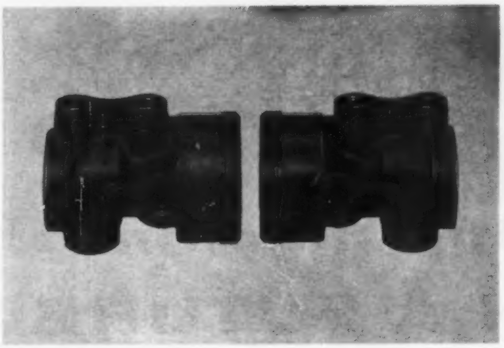
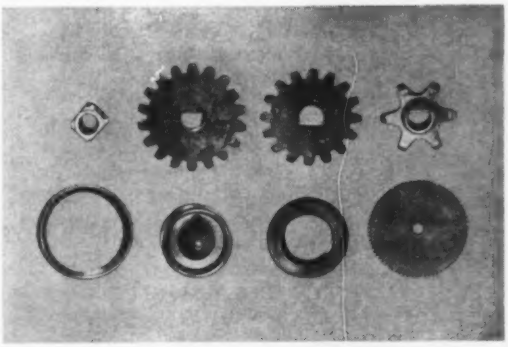


REPLACES CADMIUM PLATING . . . These grey cast iron valve bodies are used in the pneumatically operated sanders that deliver sand for improved traction under the wheels of trains, trolleys and trucks. Their manufacturer had a double-barreled problem . . . porosity in the castings was causing excessive rejects . . expensive cadmium plating was necessary to prevent corrosion in service.

Steam treating has solved both problems in one operation. Rejects due to porosity have been eliminated, and many valves previously rejected have been salvaged. Cadmium plating has been eliminated entirely because exhaustive salt spray tests showed the steam-treated finish had a higher resistance to corrosion.

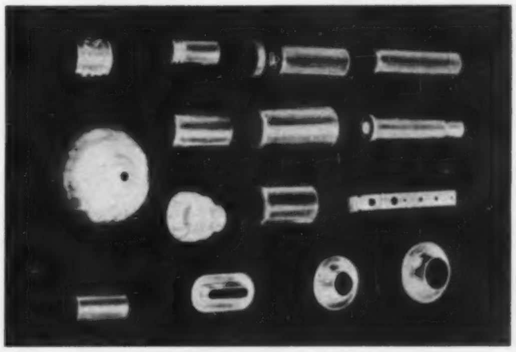
PUTS "EXTRA-LIFE" IN CUTTING TOOLS...A machinery manufacturer faced a tough problem when specifications called for milling a 0.250-inch-wide key-way slot into a piece of 4140 cold-rolled bar stock which was heat treated to a hardness of Rc 34 to 38. In addition, tolerances were tight . . . ±0.001 inch . . . with sides perfectly square.

The first high-speed steel tools used produced only four cuts and could not be resharpened because of the close tolerance. Hard-chroming the same tools improved cutter life to about 11 pieces per tool. Carbide tools held up for from 11 to 14 pieces. The next move was steam treating experimental batches of tools in an L&N furnace. The first batch averaged 100 parts per cutter, a second batch, 60 to 70 and a third lot, 100 to 125.



RAISES "PSI" OF POWDERED IRON PARTS...Although many parts made of powdered iron function satisfactorily in the as-sintered condition, there are others where an increase in hardness and compressive strength is an advantage.

This is particularly true of such parts as the steam-treated gears, cams, etc., shown above, where additional strength is needed on critical bearing surfaces. The shock-absorber piston in the center, for instance, presented a real problem . . . how to meet psi specifications for the thin-section flange around the outer edge. Steam treating proved a cheap, practical solution. Tests showed compressive strength of the flange increased from 1200 to 1400 psi. In addition, the parts, when oil dipped, had a pleasing uniform, blue-black color and high corrosion resistance.



CUTS EXPENSIVE PICKLING COSTS . . . Non-ferrous lipstick tubes and other cosmetic containers made by a large Canadian manufacturer must be annealed before finishing operations can be performed. Scale was a problem. If left on, it ruined tools and dies . . removing it meant expensive, messy pickling.

The solution was found when sample parts were annealed by the steam Homo® method. When this method was adopted as an integral part of the production line, pickling was eliminated. Subsequent figures from the cost-accounting department showed that eliminating this operation reduced annealing cost by 53 percent.

LEEDS & NORTHRUP *Pioneers in Precision*

Circle 2216 on Page 48-B

Circle 2217 on Page 48-B

NEW PRODUCTS

Nonferrous

Aluminum Extrusion Alloys

Four new products for the extrusion industry are now available from *Aluminum Co. of America.* Alloy C914 ingot, modified 6063, provides increased extrusion speed and better mechanical properties. Alloy C58 is especially suited for extrusions to be porcelain enameled. Products of alloy 6563 can be anodized to a brighter, more uniform reflective finish than other moderate-strength extrusion alloys. Alloy 4543 is used for architectural extrusions requiring a gray finish (light, medium or dark) which is produced by anodizing with the Alumilite process.

For further information circle No. 1962 on literature request card, p. 48-B

Molybdenum Mill Products

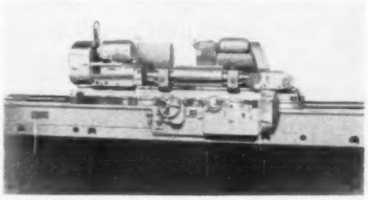
Universal-Cyclops Steel Corp. is now offering sintered molybdenum sheet in gages from 0.010 in. to 3/16 in. and widths up to 36 in. by random lengths; rolled bar products are available in diameters from 1/16 in. to 2 in. and in random mill lengths up to 10 ft. The sintered products supplement a line of arc-cast forms which include forging billet, plate, sheet, bar and wire.

For further information circle No. 1963 on literature request card, p. 48-B

Tooling

Machine for Heavy Form Grinding

Norton Co.'s research on abrasive machining has resulted in a grinding machine designed to do form grinding of rod-mill rolls. This operation takes 20 to 25% of the time formerly required in turning on a lathe. Roll materials too hard to turn can also be abrasive machined to final contour. The machine will handle rolls up to 18 in. diameter by 96 in. long and mounts wheels up to 30 in. diameter by 12 in. wide. The grinding wheel

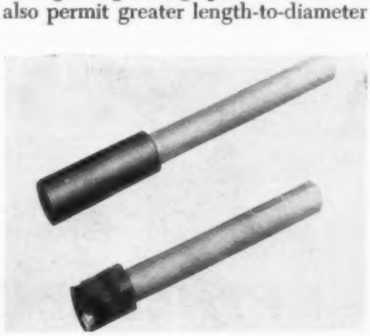


operates at 10,000 sfm. to achieve rapid stock removal and has an automatic arrangement for dynamically balancing the wheel.

For further information circle No. 1964 on literature request card, p. 48-B

WC Boring Bar Shanks

Boring bars consisting of tungsten carbide shanks and steel heads offer reduced chatter and less deflection because the rigidity of the hard carbide is three times that of tool steel. Semifinished "K-bars" produce better finishes and often eliminate extra boring and grinding operations. K-bars also permit greater length-to-diameter



KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

How Alloy Steels Respond to Induction Hardening

In the induction-hardening process, steel is first heated above the transformation range by means of electrical induction, then quenched as required. Special equipment is needed, and heat is developed as follows:

High-frequency alternating current passes through a coil or inductor, with the result that a magnetic field is created in the coil. When the piece to be treated is placed in this field, it is heated rapidly by induced energy. With the various types of induction-heating equipment, the process is capable of surface- or case-hardening to various controlled depths; however, through-hardening can be obtained with certain alloy steels. Ferrous metals that respond well to induction hardening include numerous grades of both alloy and carbon steels, as well as hardenable stainless steel and plain or alloyed cast iron.

As a rule, when alloy steels which contain non-carbide-forming elements, such as nickel, are heated by induction, the usual hardening temperatures can be used. But with alloy steels that do contain carbide-forming elements such as chromium, molybdenum, and vanadium, the hardening temperature must be increased if the normal effect of the alloying elements is desired.

Hardness obtained by the induction process is a function of the carbon content and prior structure, just as it is when conventional heating methods are used. Nevertheless, higher surface-hardness values for a given carbon content have often been noted in parts subjected to surface induction-hardening. The extra hardness may be as much as five Rockwell C points for steels of 0.30 pct carbon.

As pointed out previously, the induction method requires special equipment. However, it possesses several marked advantages, including speed of heating and cleanliness of operation. Pieces heated by induction are usually subject to a minimum of scaling and distortion. Moreover, induction-hardening equipment is very compact and therefore conserves floor space.

If you would care to know more about the induction hardening of alloy steels, please communicate with our technical staff. Bethlehem metallurgists have made a thorough study of the subject, including the many details of quenching and tempering. Call them if they can help you in any way. And remember, too, that Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

for Strength
. . . Economy
. . Versatility

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Circle 2218 on Page 48-B

ratios and an increase in feeds and speeds. Ten sizes are available ranging from 7/16 to 2½ in. diameter and from 7⅝ to 28¼ in. long. *Kennametal Inc.*
For further information circle No. 1965

WS_2 — New High-Temperature Lubricant

Tungsten disulfide, a soft, grayish-black powder, has excellent lubricating properties and higher oxidation resistance than molybdenum disulfide or graphite. Used in solid-film form or as an additive to suitable carriers, it is an effective lubricant in wire drawing, metal forming, and cutting, as well as in high-temperature valves, gears and bearings. *Sylvania Electric Products Inc.*
For further information circle No. 1966

Heating

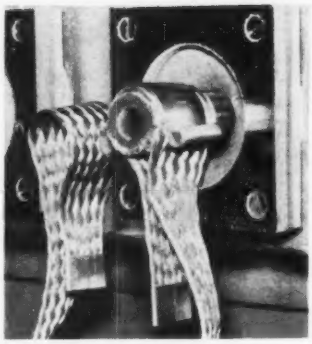
Mesh-Belt Sintering Furnace

Designed for sintering and infiltrating, a new furnace from *Harper Electric Furnace Corp.* features positive counterflow of atmosphere gas, proper disposal of volatiles, easy ash removal, rapid duplication of belt speeds, and accurate control of temperature. The operating characteristics

of the "Model M" furnace insure dimensional stability and part strength. Strains within pressed compacts are relieved gradually since the parts are heated slowly and soaked at uniform temperature in the burnoff chamber. Heating chamber lengths range from 3 to 11 ft. and mesh belt widths from 6 to 36 in. The burnoff and high-heat chambers can be gas fired or electrically heated.
For further information circle No. 1967 on literature request card, p. 48-B

Seal for High-Temperature Furnaces

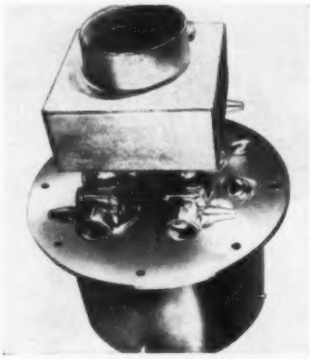
This terminal seal was developed by *Hevi-Duty Electric Co.* to replace the box-type enclosure ordinarily used over the ends of silicon carbide heating elements. Use of the new seal reduces furnace shell temperature,



simplifies maintenance, and eliminates the explosion hazard. Flexible gaskets which fit around the heating elements make the new seal leakproof and a wire screen guard prevents contact with the terminals.
For further information circle No. 1968 on literature request card, p. 48-B

Multiple Tunnel Burners

A four-flame gas burner made by *Pyronics Inc.* produces 4,000,000 Btu. per hr. with a 2-ft. flame length, suitable for firing into restricted areas or into pressurized combustion chambers. Individual flames, with a turndown ratio of 40:1, provide a minimum capacity of 50,000 Btu. per hr. in the "2004NM" model. Capacities can be

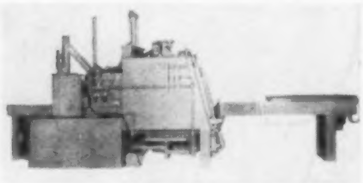


increased up to 70% with higher air and gas pressures. The units, which burn any standard fuel gas, are equipped with standard pilots and flame detectors.
For further information circle No. 1969 on literature request card, p. 48-B

Infrared Gas Burner

The "Type K" burner, with a higher conversion ratio (fuel to infrared energy) than any other infrared burner, provides increased efficiency in drying, curing, heat treating, and baking operations. The K-burner, 6⅝ in. wide, comes in 2½, 4½ and 7-in. lengths, which can be mounted end-to-end to provide continuous heat radiators up to 100 ft. long. The burner features controlled fuel input to each section which permits "profiling" heat output to meet varying requirements across the product being treated. *Red-Ray Mfg. Co.*
For further information circle No. 1970

Versatile Gas-Fired Furnace



Used for carburizing, carbonitriding, carbon restoration, normalizing, annealing and hardening at temperatures from 1400 to 2000° F., this controlled atmosphere furnace is designed so that no part of the transfer system is exposed to heat except when work is being processed. Available in five sizes, with heating chamber dimensions ranging from 12 by 12 by 18 in. long to 30 by 24 by 48 in. long, the furnace has production rates ranging from 100 to 1000 lb. per hr. *Sunbeam Equipment Corp.*
Circle No. 1971 on request card, p. 48-B

Variable Temperature Chamber

A testing chamber made by *Cincinnati Sub-Zero Products* can test 150 parts simultaneously over a range from −100 to 350° F. The "Model SU-100-10-HC", with 10 cu. ft. capacity, is adapted to nondestructive as well as life testing of diodes, resistors, capacitors, transistors, and other component parts. Thermal capacity of the unit is 400 Btu. per hr. at −80° F.; an air baffle assures even temperature distribution by eliminating hot spots and stratification.

For further information circle No. 1972

Continuous Annealing Furnace

General Electric Co. announces a high-production furnace for the continuous annealing of aluminum, copper, or brass strip. Since every square

MUELLER CAN MAKE MOST ANYTHING IN BRASS OR ALUMINUM FORGINGS...

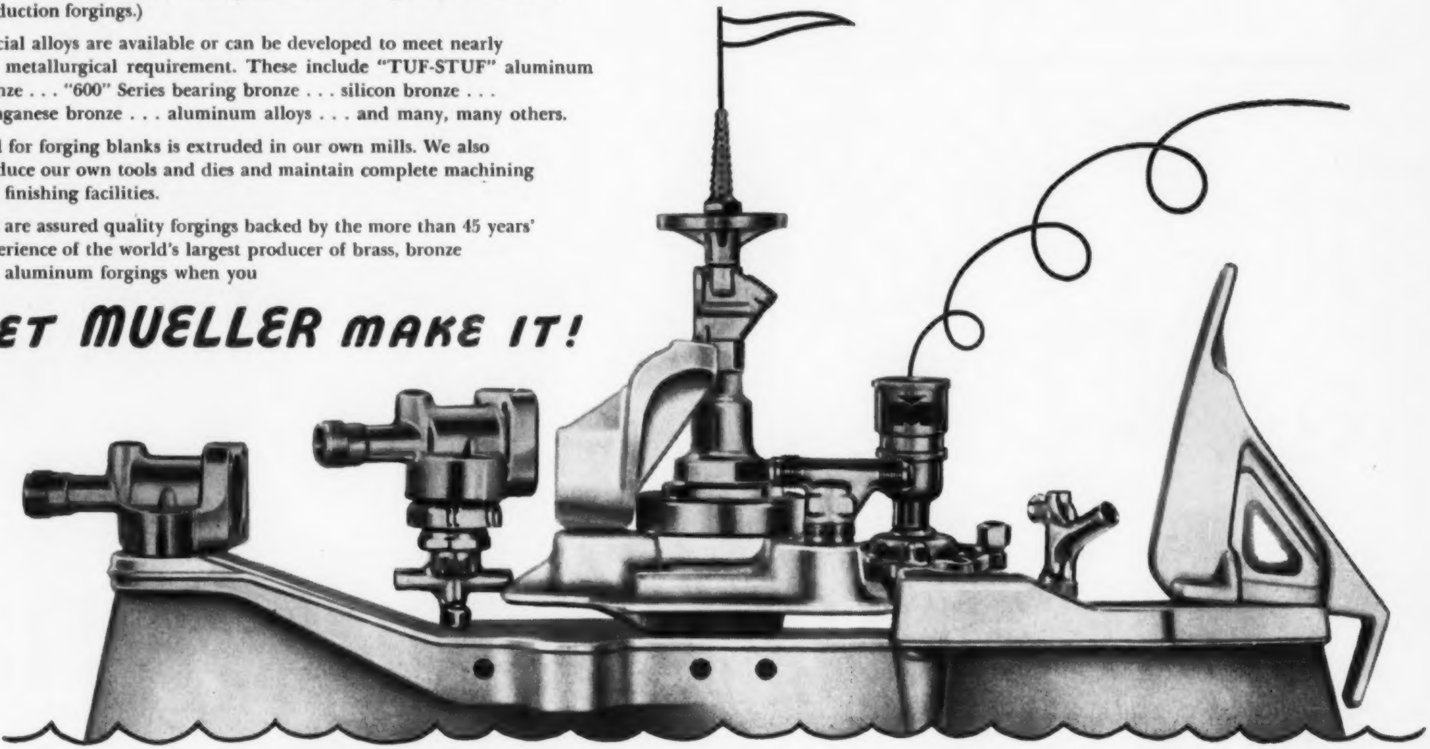
Battleships are not our business, but we can make any practical size and shape forging, including cored forgings and those with bosses or cavities on two planes. (The ship model is made up from a number of production forgings.)

Special alloys are available or can be developed to meet nearly any metallurgical requirement. These include "TUF-STUF" aluminum bronze . . . "600" Series bearing bronze . . . silicon bronze . . . manganese bronze . . . aluminum alloys . . . and many, many others.

Rod for forging blanks is extruded in our own mills. We also produce our own tools and dies and maintain complete machining and finishing facilities.

You are assured quality forgings backed by the more than 45 years' experience of the world's largest producer of brass, bronze and aluminum forgings when you

LET MUELLER MAKE IT!



Write today for Engineering Manual FM-3018

MUELLER BRASS CO.
PORT HURON 28, MICHIGAN

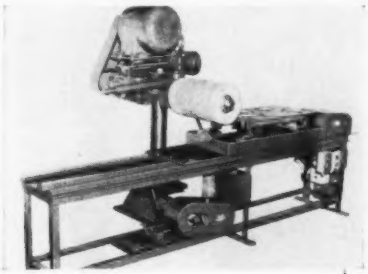
Circle 2223 on Page 48-B

inch of each coil receives the same treatment in the furnace, the strip is uniform in grain size, properties, and surface condition. Strip passing through the furnace cannot be scratched, since it touches nothing during heating or cooling. Heat input to the furnace may be varied by a ratio of 8 to 1 while maintaining accurate control of the products of combustion.
For further information circle No. 1973

Finishing

Straight-Line Buffing Machine

This automatic machine is used for buffing and satin finishing of flat parts such as sink and table tops. A timer permits work to reciprocate under the wheel for a predetermined period. An oscillating feature provides uni-



form wheel wear, eliminates buff streaking, and permits the use of buffing lathes that do not incorporate stroking-type spindles. *Acme Mfg. Co.*
For further information circle No. 1974

Ultrasonic Equipment

Ultrasonic equipment can only do half a job if the properly formulated compounds are not used. Therefore, in addition to its present line of over 600 chemical cleaning and processing compounds, *Turco Products, Inc.* has added ultrasonic generators (125 to 25,000 watts) and tanks ranging from 1½ to 36 gal. The equipment can clean parts made of aluminum, brass, magnesium, stainless steel, ceramics, and many other materials. Components cleaned by this process include jet engine filters, bearings, electrical circuits, and missile parts.
For further information circle No. 1975

Welding

Plate-Edge Preparation

Using standard machine cutting torches with acetylene, natural gas or propane, the "Model PE-1" plate-

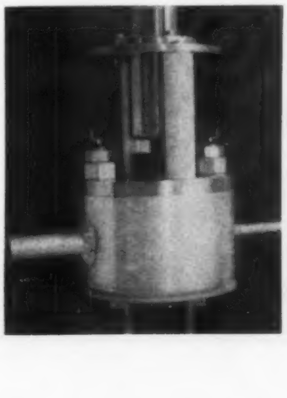
edge preparation unit can accurately cut straight edges as well as single bevels, double bevels or bevels with a nose. Cutting nozzles float freely as a guide wheel moves over the work surface. This assures smooth, uniform cuts by maintaining the proper nozzle-to-workpiece distance regardless of surface contour. The unit can be mounted on a flame-planer bridge, a side-beam carriage, or a portable machine carriage. *Linde Co.*
For further information circle No. 1976 on literature request card, p. 48-B

Flash-Butt Welders

Sciaky Bros., Inc. is introducing a series of air-operated flash-butt welders designed to weld a wide range of metals including low-carbon and stainless steel as well as aluminum and copper alloys. Available in 20, 50, 100 and 150-kva. sizes at 50% duty cycle, the "BPR.O" series of low-impedance, single-phase welders can accommodate a maximum stock width of 6 in., a maximum stock diameter of 3 in., and a minimum diameter ring of 5 in. Upset force up to 20,000 lb. and clamping force up to 30,000 lb. is provided. The pneumatic flashing and upsetting systems are each independently adjustable.
For further information circle No. 1977

Electron Beam Gun

The "Model 2025G", made by *High Vacuum Equipment Corp.* can be used for welding refractory and re-



The Porter Alloyist delivers the right alloy IN THE SPOTS THAT COUNT

active metals and other difficult-to-weld alloys. Self-accelerated, the unit incorporates electrostatic deflection for moving the beam electronically within a 3-in. circle. Operating in stainless steel bell jars, or in larger chambers for production work, the gun can be moved mechanically to provide further versatility in welding. Rated 20 kv., 5 kw., the unit can also be used for button melting, zone refining, and thin-film deposition.
For further information circle No. 1978

Air-Cooled Welding Torch

An air-cooled TIG holder features a thumb-operated gas valve for increased speed and economy. Ideal for welding thinner gages of aluminum, stainless steel, copper, and magnesium, the "H-16B" holder is

rated 160 amp. a-c. or d-c. continuous. A variety of alumina nozzle sizes are available in 1¼ and 1⅝ in. lengths; argon, helium, or mixtures of both shielding gases can be used. The holder minimizes stub loss and eliminates high-frequency leakage. Tungsten electrodes from 0.20 through 5/32 in. diameters and from 2 to 7 in. long can be accommodated. *Air Reduction Sales Co.*
For further information circle No. 1979

Testing

Detecting Flaws in Moving Metal

"Flux-Flaw" equipmen such elusive flaws as poor and laminations in contin

ing metal. The equipment is also used to find butt welds in coils of coated or uncoated wire and tubing. The unit can easily distinguish between what it is seeking and unwanted background "noise." Replaceable electronic modules permit the unit to be adapted to a variety of testing applications, including conventional eddy current techniques. *Assembly Products, Inc.*
For further information circle No. 1980

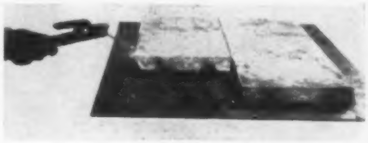
Power Controller

A power control device, replacing saturable core reactors, is used in conjunction with a "Speedomax H" current-adjusting unit to control electrically heated metal processes. The silicon rectifier unit is smaller and lighter, and has a faster speed of response, a wider control range, and more linear control for directing signal input and power output. *Leeds & Northrup Co.*
For further information circle No. 1981

Casting

Weld-in-Place Refractory

Introduced by *Corhart Refractories Co.*, each fusion-cast refractory shape contains a steel lug which is arc welded directly to the structure to be protected; installation is quicker, easier, and less costly. The zirconium-



aluminum-silica product, "Corhart ABR", is used in areas where abrasive attack occurs as a result of moving bulk material such as coke, sinter, ore, taconite, and hard pelletized materials. Available sizes include rectangles 1, 2, 3, or 4 in. thick and 4 to 12-in. pipe liners.
For further information circle No. 1982

Parts

Spring-Making Machinery

The "Springenerator" can produce springs in a single operation at rates from 720 to 6000 per hr., and the shape of the end loop does not affect production rates. Recent design changes have resulted in a smoother working machine, longer machine life and easier maintenance. The Springenerator accepts wire 0.008 to 0.034 in. in diameter and offers a load tolerance of ±5%. *Baird Machine Co.*
For further information circle No. 1983

This is a P&H engine-driven welder.
We make 10 different kinds.
All sizes. All good. All dependable.
Nothing fantastic about how they work.
They just weld good like they should.
Know why?

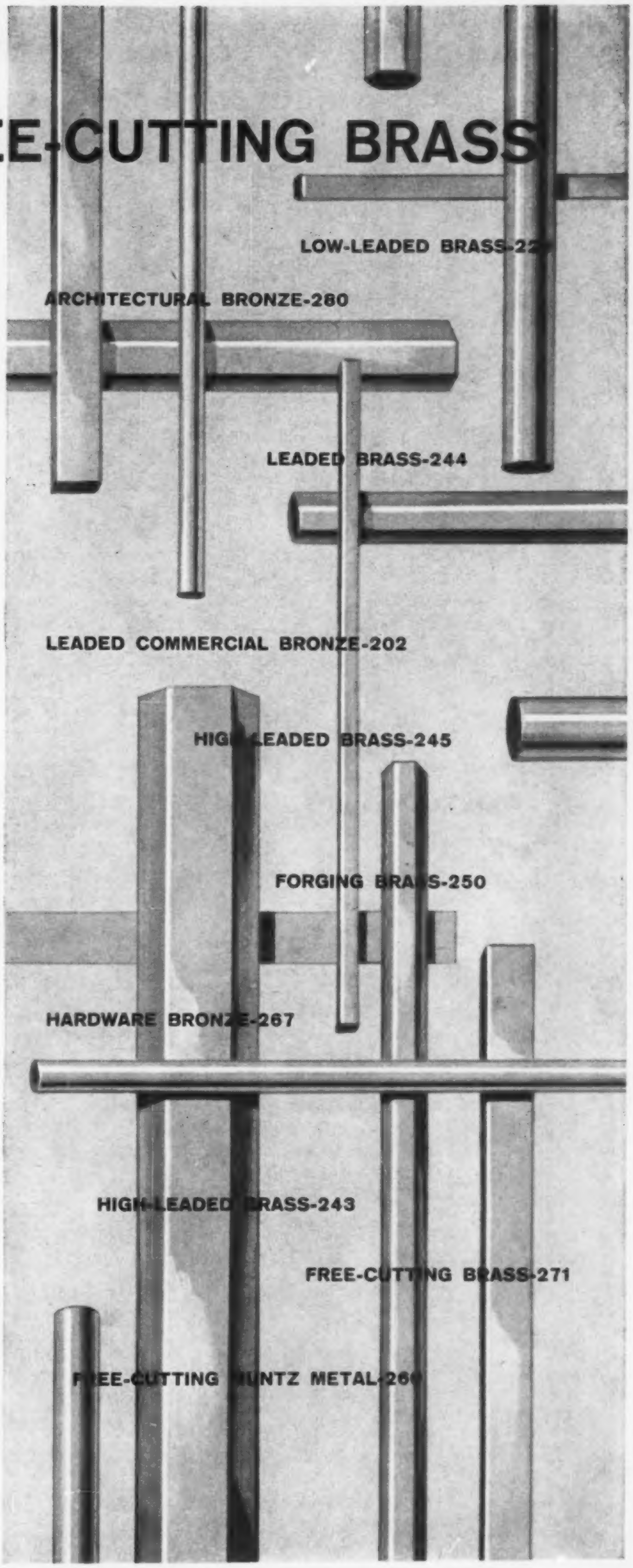
We build 'em as though we were going to buy'em ourselves!

Know a better guarantee of quality?

HARNISCHFEGER P&H WELDING PRODUCTS DIVISION

Milwaukee 46, Wisconsin

ANACONDA FREE-CUTTING BRASS



Free-Cutting... Cost-Cutting

Year after year after year, engineers who know brass select Anaconda Leaded Brasses for their special characteristics and qualities.

The superior machining qualities of Anaconda free-cutting brass rod permit the use of heavy feeds and high cutting speeds. Tool life is much longer; tool breakage considerably less. Close tolerances are held for longer continuous runs. What's more, you get fewer rejects, more accurate assemblies, and products with better appearance.

When you buy or specify Anaconda American Brass, you can choose from nearly 300 different alloys . . . the greatest range of sizes, shapes, tempers and characteristics in Copper and Copper Alloys. Contact your Anaconda representative or write: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 61-1147

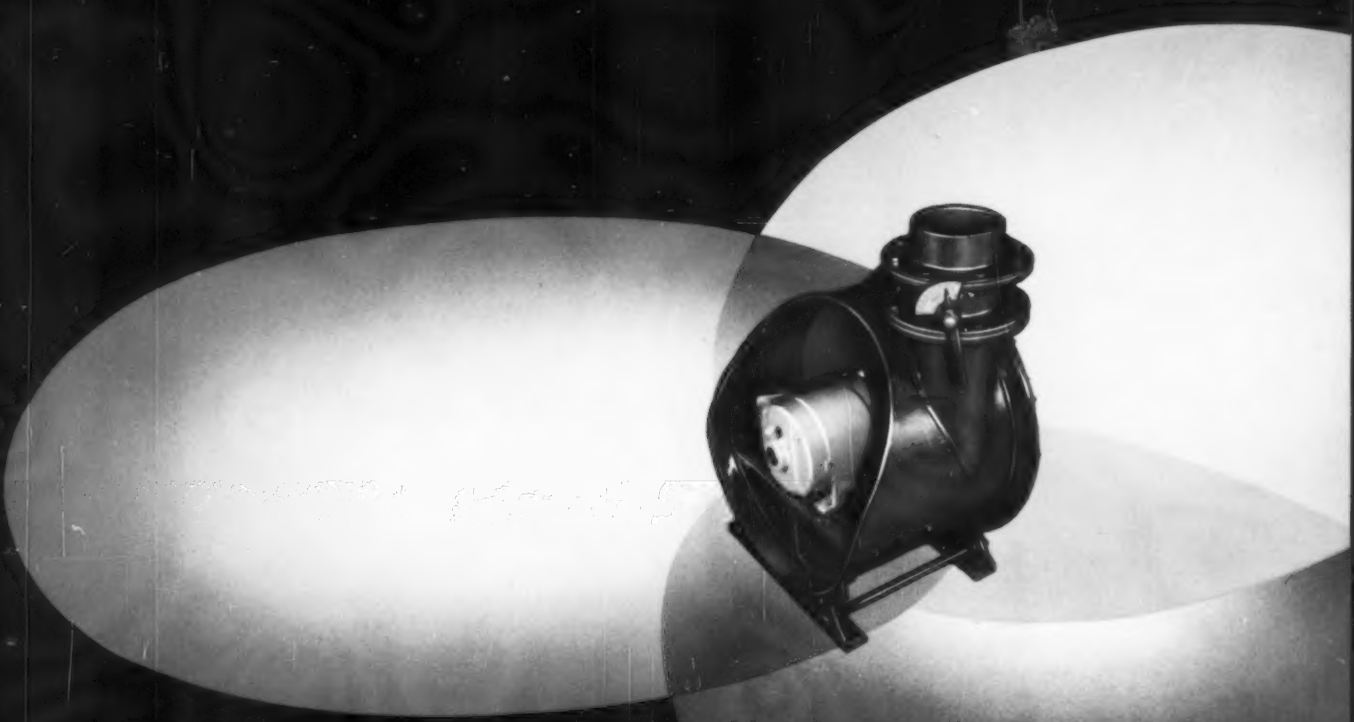
FREE CUTTING BRASS

a product of

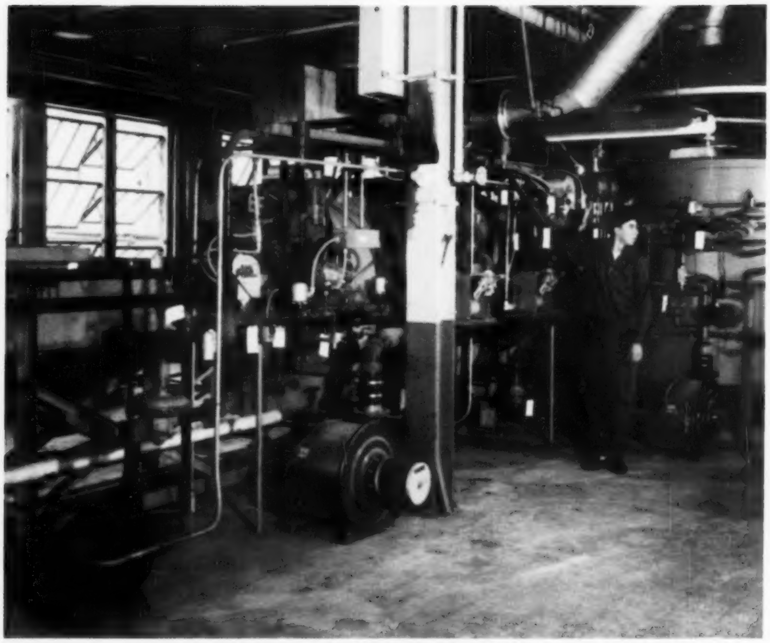
ANACONDA®

AMERICAN BRASS COMPANY

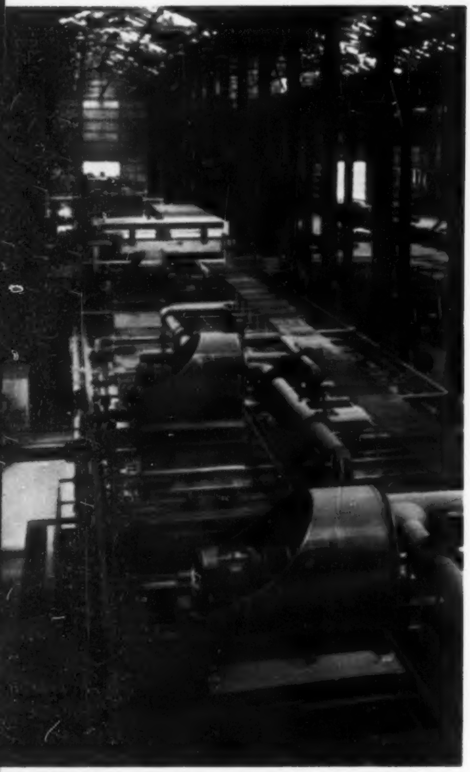
Circle 2226 on Page 48-B



SPENCER BLOWERS



Three Spencer blowers (on floor, left, center and right) on Electric Furnace Company gas fired, special atmosphere annealing furnace at Bridgeport Brass Company.

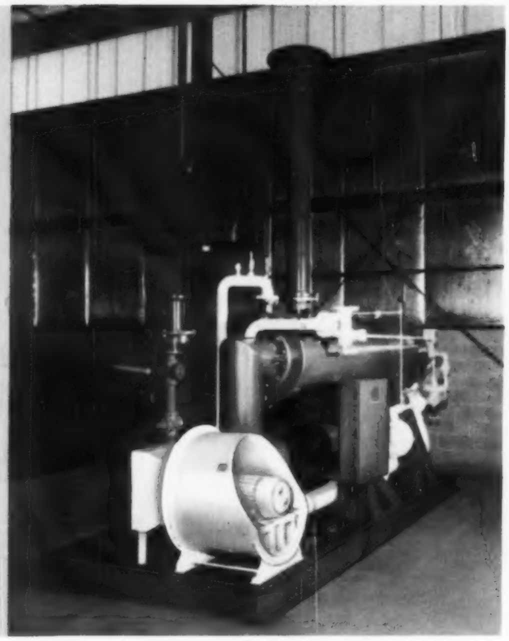


Spencer blowers atop Drever tempering furnace at Sheffield Div., Armco Steel Corp., Houston, Texas.

...preferred because of their

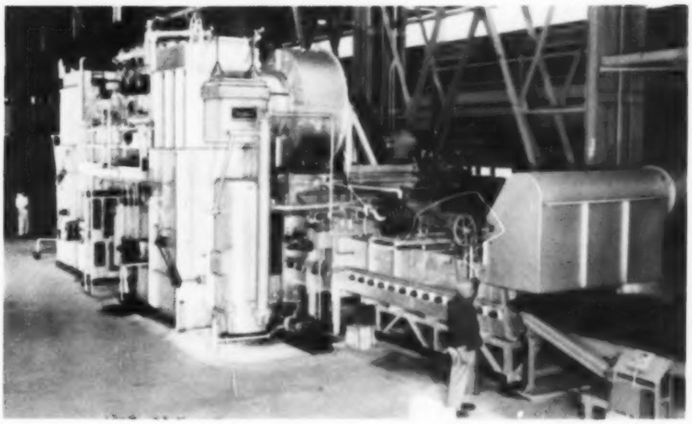
On a wide variety of applications throughout the metalworking industry, Spencer blowers daily are demonstrating their dependability. The famous Spencer "sugar-scoop" silhouette is seen wherever uninterrupted delivery of high volume, low pressure air must be assured.

Spencer blowers—also referred to as Turbo-Compressors because of their turbine type construction—are of the centrifugal type and increase air pressure in stages by means of lightweight impellers.



Spencer blower supplies combustion air to Kemp inert gas generator.

Spencer blower on Surface continuous roller hearth bright annealing furnace in finishing line of Scovill Manufacturing Company's tube mills, New Milford, Conn.



SPENCER BLOWERS

A single Spencer blower (upper left) serves entire melting line at The American Hardware Corp., world's largest maker of locks and builder's hardware.

proven reliability

Among the many reasons why Spencer blowers are preferred:

RUGGED CONSTRUCTION—Sturdily built and solidly positioned on a bridge-like base . . . yet compact in design, with no unnecessary bulk.

RELIABLE OPERATION—Because lightweight impellers with wide clearances are the only moving parts, wear is reduced . . . long term, uninterrupted operation is assured.

EASE OF MOUNTING—Absence of vibration simplifies attachment . . . eliminates need for special mounting . . . permits freedom in positioning.

LOW OPERATING COSTS—Significant operating savings are realized because power used is in direct proportion to air delivery required under varying conditions.

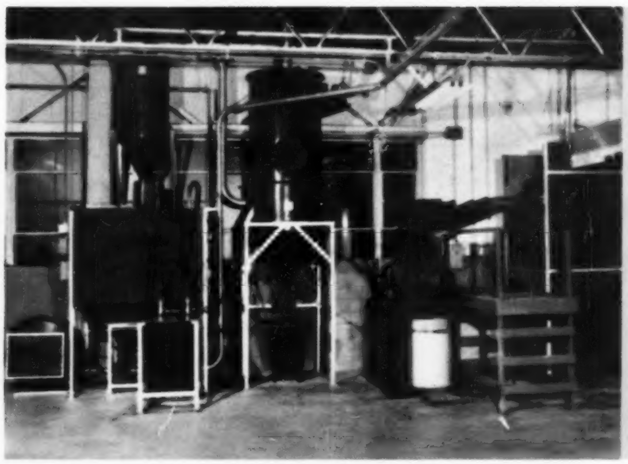
NON-CONTAMINATION FEATURE—Because all bearings are outside of casing, there can be no oil contamination. Delivery of clean air is assured.

Standard models are available in capacities from ⅓ to 1,000 H.P. . . . up to 20,000 C.F.M. . . . 4 oz. to 10 lbs. pressure. For complete technical information request Catalog No. 126C.

Built-in vacuum cleaning systems help to keep microscopic dust particles out of critical aerospace components at Barden Corp., producer of precision instrument bearings.

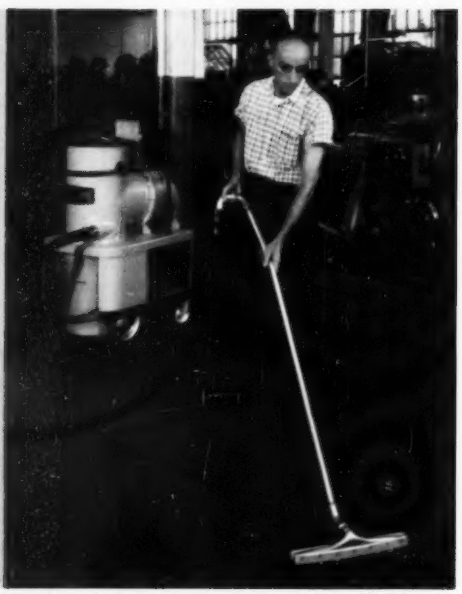
Request Catalog No. 155B

other spencer products



Pneumatic conveying system at Columbia Records Co. plant, Terra Haute, Indiana, speeds movement of plastic pellet material to automatic record presses, eliminating excessive labor in distribution of material. Portable or installed systems available in capacities to 100 H.P.

Request Catalog No. 143B



Heavy duty portable vacuum cleaners—available in sizes from ½ H.P. to 100 H.P.—fill a wide range of industrial, commercial and institutional requirements.

Request Catalog No. 155B

SPENCER

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

IN HEAT TREATING HIGH-SPEED STEELS

. . . No other method including vacuum heating matches salt bath speed, quality of results, uniformity and freedom from localized overheating, grain growth, distortion and excessive carbide solution!

This commercial heat treaters' high-speed Ajax salt bath installation has meant

Uniform...Decarb-free...Straighter Work

HARDENED 2 TO 3 TIMES FASTER!

When Benedict-Miller Inc., well-known commercial heat treaters of Lyndhurst, N. J. installed their Ajax high-speed salt bath furnace they expected a lot in the way of better, lower cost results—and got even more! Here, after 3 years of constant use, is the way it stacks up:

WORK HANDLED IN 50% - 75% LESS TIME!

Regardless of size, shape or type of high-speed work, loads are handled in from 2½ to 4 hours as compared to 7 or 8 hours previously.

CHEAPER FIXTURES..... FASTER FIXTURING

Costly special alloy trays that necessitated painstaking fixturing of the work have been replaced with simple, easily-loaded carbon steel fixtures.

OUTSTANDING RESULTS ON T-TYPE COBALT STEELS.....

Hardness of R_c 66-68 is consistently obtained on critical cobalt steels such as T_2, T_4, T_5 and T_6. Decarburization is not a factor. Finish grinding is seldom needed. (Previously a minimum of .010" had to be allowed for grinding even though protective coatings were used on the work to reduce decarburization.)

PLUS THESE ADDITIONAL ADVANTAGES!

The same Ajax furnace and the same salt operate at any required temperature between 1750° and 2350°F. . . .

One daily rectification maintains bath neutrality. . . .

Partial hardening can now be done as needed. Because salt bath heating is so much faster than other methods, there is no danger of oversoaking light sections of pieces of varied thickness . . .

. . . And furnace maintenance has been lower than their best expectations.

AJAX

SALT BATH FURNACES

Internally heated electric and gas-fired types

AJAX ELECTRIC COMPANY
910 Frankford Ave., Philadelphia 23, Pa.

Foreign Licensees: AUSTRALIA: Birlec Major Proprietary, Ltd., Victoria. ARGENTINA: Master Argentina, S. A., Buenos Aires. BRAZIL: Organicacao Industrial Fides, S. A., Sao Paulo. ENGLAND: Imperial Chemical Industries Ltd., Oldbury.

Circle 2227 on Page 48-B

HARNESSING THE ELECTRON BEAM

WHAT IS E-BEAM EQUIPMENT? WHAT DOES IT DO? CAN IT BE PUT TO WORK FOR YOU ECONOMICALLY?

WHAT IT IS: Alloyd Electronics' electron beam equipment consists of a line of completely self-contained units employing electron bombardment heating, carried out in a vacuum, for evaporating, welding, brazing or zone refining.

MAJOR APPLICATIONS:

Evaporation: Alloyd electron beam equipment can be used to produce high purity thin metallic and non-metallic films by vapor deposition of high temperature materials. Films can be made from the most difficult materials, including beryllium, tantalum, silica, alumina.

Useful thin-film applications: Electronics, where thin films can perform as capacitors, resistors, magnetic memory devices, etc. . . . optics, where thin films with unusual optical properties are being developed . . . and countless other applications.

Welding: Alloyd Electron Beam Welders (see below) are designed for experimental or production welding and brazing of refractory and reactive metals. High vacuum is coupled with high power density — makes possible contamination free, narrow heat affected zone welds in titanium, beryllium, tungsten, molybdenum, etc.

MAJOR ADVANTAGES OF ALLOYD EQUIPMENT: 1. Modular design, for flexibility: basic components of any Alloyd system, including electron gun and power supply, vacuum chamber, and vacuum pumping system are available in practically unlimited combinations for maximum flexibility, and can be easily and economically tailored to any application. 2. Voltage is low and safe (30,000 volts max.) eliminating x-ray hazards to the operator. 3. Maintenance is simplified. For example, the electron gun filament in any Alloyd unit can be serviced without removing the gun. 4. Operation is simplified. Fingertip controls, located directly underneath the chamber, make for maximum operating ease and efficiency.

Benefits to be derived from Alloyd's look-ahead modular design are both numerous and substantial, not only in terms of reliability, but in terms of flexibility and cost.

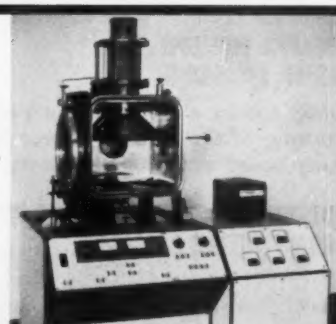
It will be well worth your while to write today for complete information.

alloyd electronics corporation 35 Cambridge Parkway, Cambridge 42, Massachusetts

Mark VI Electron Beam Welder — for clean, crack-free welds in even the most refractory and reactive metals by electron bombardment. High vacuum eliminates contamination. Ultra-narrow heating zone permits optimum control and precision in handling very thin pieces or welding thin-to-thick sections.

Mark V Electron Beam Evaporator — a reasonably priced, highly flexible unit for producing thin metallic and non-metallic films by vapor deposition through electron bombardment heating. Completely self-contained. An invaluable research and development tool for thin-film applications, including micro-miniaturized electronic circuitry, optical filters, resistors, capacitors, memory devices, countless other components.

The Electron Beam at your service — Our laboratory is part of an advanced, complete facility for electron beam welding, brazing, evaporating, melting and zone refining maintained by Alloyd to meet custom requirements. We also offer engineering, consulting and R&D services in systems design and development. Ask us for complete information.



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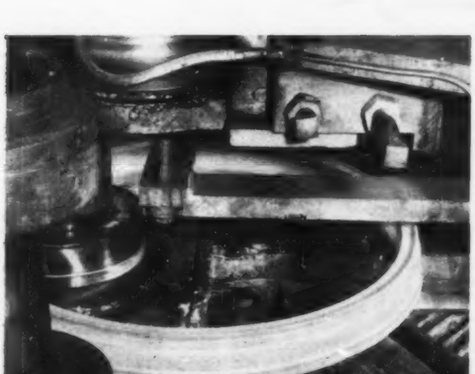

Manufacturer uses ring-roller to shape turbine seal rings made of HASTELLOY alloy X

The surging power of modern 20,000-pound thrust jet engines is being harnessed effectively by critical parts made of HAYNES high-temperature alloys. Turbine seal areas are typical of the hot spots in which these alloys serve. Here, in the form of turbine seal rings, they contain the hot combustion gases as they roar through the various turbine stages.

In these, and in other parts too, such as afterburner liners, flame holders, shrouds, and investment-cast turbine blades and nozzle vanes, HAYNES alloys are resisting the punishing effects of long hours at high temperature. In fact, one of the Air Force's latest 1500-MPH jets uses six different HAYNES alloys in vital parts where heat and stress would weaken and fatigue other materials.

Whether investment- or sand-cast, rolled, wrought, vacuum melted, or air melted, there's a HAYNES high-temperature alloy to meet your needs.

HAYNES
ALLOYS

HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

Address inquiries to Haynes Stellite Company, 270 Park Avenue, New York 17, N.Y.

Circle 2229 on Page 48-B

METAL PROGRESS

NEW LITERATURE

Steel

1986. Zinc-Coated Steel
Brochure from *Armco Steel Corp.* details the advantages of "Zincgrip A, Paintgrip," a new kind of hot-dip zinc-coated steel especially prepared to take a paint finish which is as attractive as the paint finish on cold-rolled steel. It's spangle-free, holds paint tighter and longer and permits twice as many spot welds as ordinary galvanized steel.

1987. Precipitation-Hardening Stainless
32-p. booklet from *Republic Steel Corp.* contains data on heat treatment, chemical properties, fabricating characteristics and applications for all precipitation-hardening stainless steels.

1988. Austenitic Stainless
8-p. booklet explains nature and occurrence of sigma phase, as well as its chemical composition, identification, and effect on mechanical properties and corrosion resistance. *Electric Steel Foundry Co.*

1989. PH Steels
Republic Steel Corp. offers literature on 17-7 PH and PH 15-7 Mo stainless steels for improved properties and formability.

1990. Alloy Steel Applications
Product and Facilities Catalog on "Aristoloy" alloy applications, leaded and unleaded grades. *Aristoloy Steel Div.*

1991. Metallurgical Education
32-page catalog covers courses on all phases of metals engineering including elements of metallurgy, welding, heat treatment and foundry. *A.S.M. Metals Engineering Institute.*

1992. High-Strength Steel
"N-A-XTRA" high-strength steels are available at four levels of minimum yield strength from 80,000 to 110,000 psi. Information from *Great Lakes Steel Corp.*

1993. Columbium Steels
Columbium in steel improves strength and weldability with only a minor loss in ductility. For more information, send for reprint "Columbium in Carbon Steels". *Union Carbide Metals Co.*

1994. Specialty Bolts
Republic Steel Corp. has prepared a brochure reviewing applications for specialty bolts and nuts.

1995. 17-4 PH Stainless
Armco Steel Corp. has published data on 17-4 PH stainless steel; stronger than Type 416, with corrosion resistance in the 18-8 class.

1996. Tool Steel Selector
The *Allegheny Ludlum* tool steel "Steelector" booklet contains selector cards, descriptions of the various tool steel grades, and explains individual "Data Stock lists" available for each grade.

1997. Alloy Steel Booklet
"Quick Facts About Alloy Steels", published by *Bethlehem Steel Co.* Elementary information on steel heat treatment, properties, and microstructures.

Nonferrous

1998. Cobalt-Base Alloys
These alloys have low coefficients of friction and are unusually long lasting under metal-to-metal wear conditions. 32-page booklet from *Haynes Stellite Co.*

1999. Data on Light Metals
Design data on characteristics and properties of light metals (magnesium, aluminum and titanium) is contained in 44-page booklet prepared by *Brooks & Perkins, Inc.*

2000. Zirconium Products
"Zirconium Data File" gives information on production of zirconium and hafnium smelting, wrought products, alloys and properties, fabrication, and applications. *Carborundum Metals Co.*

2001. "Handbook of the Alloyist"
Discusses advantages of several groups of alloys used in the electrical and electronics industries. Properties and typical applications are given. *H. K. Porter Co.*

2002. Molybdenum Sheet
A.S.T.M. reprint presents data on properties and applications of molybdenum-base sheet. *Climax Molybdenum Co.*

2003. Bronze Alloys
Special characteristics of copper-base alloys make them ideal for applications where corrosion, erosion, abrasion or metal-to-metal wear are encountered. Pamphlet from *Ampco Metal.*

2004. Aluminum-Lithium Alloys
Report 4073 on the physical and mechanical properties of some aluminum-lithium alloys has been issued by *Lithium Corp. of America, Inc.*

2005. Ductile Vanadium
Vanadium Corp. of America has published "Ductile Vanadium: Techniques That Make Fabrication Easier", which discusses new fabricating techniques for hot worked and cold worked ductile vanadium including annealing range, extruding methods, machining and welding.

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2006. Cold-Heading Wire
Cold-heading and upsetting operations require specific qualities in wire to obtain optimum quality at minimum cost. Publication B-33 gives the details. *Anaconda American Brass Co.*

2007. "Tin News"
The Malayan Tin Bureau offers free subscription to monthly bulletin covering tin supply, prices and new applications.

2008. Aluminum Extrusions
Aluminium Limited Sales, Inc., will provide you with a list of independent extruders who can give you fast service on your requirements for aluminum mill shapes.

2009. Special Alloys
H. K. Porter Co. has prepared booklet entitled "Alloys for Industry" discussing alloys such as phosphor bronze, nickel silver, cupronickel, brass, Monel and Inconel.

2010. "More Zr Facts"
Bi-monthly published by *Carborundum Metals Co.* presents physical, nuclear and mechanical properties as well as fabrication techniques for zirconium and its alloys.

2011. Nickel Alloys
International Nickel Co. has application data and engineering information on nickel, its alloys, and the various grades of stainless for unusual conditions of stress, fatigue, heat or cold, or corrosion.

2012. Cobalt and Nickel-Base Alloys
4-page data sheet lists physical and mechanical properties, corrosion resistance, thermal treatments, fabricating data, available forms, and applications of 13 alloys. *Cobalt Information Center.*

Materials

2014. Diffusion Coatings
Folder from *Haynes Stellite Co.* discusses diffusion coatings—hard, nonporous surfaces for metals and alloys which increase oxidation resistance at temperatures to 2300°F.

2015. Refractory Materials
Booklet from *Norton Co.* describes many refractory materials employed in applications such as protecting rocket engines, handling molten metals, or in chemical processing.

2016. High-Temperature Ceramics
Catalog contains information on space-age ceramic compositions such as alumina, magnesia, thoria, zirconia and others. Includes list of sizes and prices for crucibles and tubing as well as data on custom ceramic items. *Laboratory Equipment Corp.*

2017. Tungsten and Molybdenum
Sylvania Electric Products can now supply tungsten or molybdenum ingots up to 10 in. diameter and up to 4 ft. long; also forging billets, electrodes for arc casting, blanks for machining or machined blanks ready for your use.

2018. Thermal Fatigue
Electro-Alloys Div. will send you a report entitled "The Mechanism of Thermal Fatigue", by H. S. Avery.

2019. Corrosion Data Charts
The corrosive effects of 400 different materials on 16 different alloy systems—including Hastelloys, Monel, nickel, Inconel, aluminum, tantalum, titanium and zirconium—are shown in data chart published by *Nooter Corp.*

2020. "Abrasion Resistance of Refractories"
8-page reprint presents results of abrasion tests on refractory brick and monoliths. *Harbison-Walker Refractories Co.*

2021. High-Temperature Alloys
68-page loose-leaf booklet includes data on 23 high-temperature alloys produced by vacuum induction or consumable electrode methods. *Carpenter Steel.*

2022. Bibliography on Superalloys
Special Metals Inc. has prepared a 24-page booklet entitled "Three Superalloys: a Selected Bibliography Relating to Udimet 500, Udimet 700 and René 41".

1985. Molybdenum Products
57-page brochure issued by the *Metallwerk Plansee A.G.* of Austria, Europe's largest refractory metals producer, describes the properties of molybdenum metal, its availability

in mill supply forms and various fabricated shapes, and its present applications in industry. Included in the text is a section on how to machine and work the metal to finished form. *Schwarzkopf Development Corp.*

2023. Inconel Alloy
Technical Bulletin T-7 sets forth the details on Inconel, a nickel-chromium alloy with outstanding corrosion resistance and good high-and-low temperature properties. *Huntington Alloy Products Div.*

2024. Space-Age Ceramics
The *Coors Porcelain Co.* has released literature discussing the "Rokide Process" for producing oxide coatings on the surface of metals to withstand high-temperature environments.

2025. Chromallizing
This process diffuses one or more elements into the surface of steels, superalloys, or refractory metals to protect them from oxidation at high temperatures. Information from *Chromalloy Corp.*

2026. Silicon Carbide
Norton Co. has prepared pamphlet on "Crystolon 63" a low cost nitride-bonded silicon carbide refractory.

2027. Corrosion-Resistant Steels
60-page booklet entitled "The Role of Molybdenum and Copper in Corrosion Resistant Steels and Alloys". *Climax Molybdenum Co.*

2028. Refractory Metal Chart
Offered by *Fansteel Metallurgical Corp.* Lists the properties of the refractory elements tungsten, tantalum, molybdenum, and columbium.

2029. High-Temperature Alloy
16-page booklet discussses "Haynes Alloy 56", a lower-cost, high-temperature alloy with good strength and oxidation resistance in the 1200 to 2000° F. range. *Haynes Stellite Co.*

2030. 1800 to 2300° F. Service
"Supertherm" is a 26% Cr, 35% Ni alloy stabilized with cobalt and tungsten. Application information and other details available from *Electro-Alloys Div.*

2031. Zirconium Oxide
Folder from *Zirconium Corp. of America* presents the facts on "Zircoa" zirconium oxide refractory grains for high-temperature applications.

2032.—Molecular Bonding
The molecular bonding process is described in 12-page leaflet from *Al-Fin Corp.* Aluminum can be bonded to low-carbon, or alloy steel, Kovar, cast iron, molybdenum or stainless steel.

2033. Tungsten and Molybdenum
General Electric Co. has prepared brochure on properties and applications of tungsten and molybdenum.

2034. Arc Crystal Tungsten
Linde Co. will send details on arc crystal tungsten—ingot of crystal bar tungsten melted in arc furnace—which possesses unusual ductility and high degree of workability.

2035. Inconel Alloy
Alloy 718 is the strongest wrought alloy available for use in the temperature range 800 to 1300° F. The alloy can be welded in the age hardened condition. Slow aging response provides easy fabrication. *Huntington Alloy Products Div.* will send details.

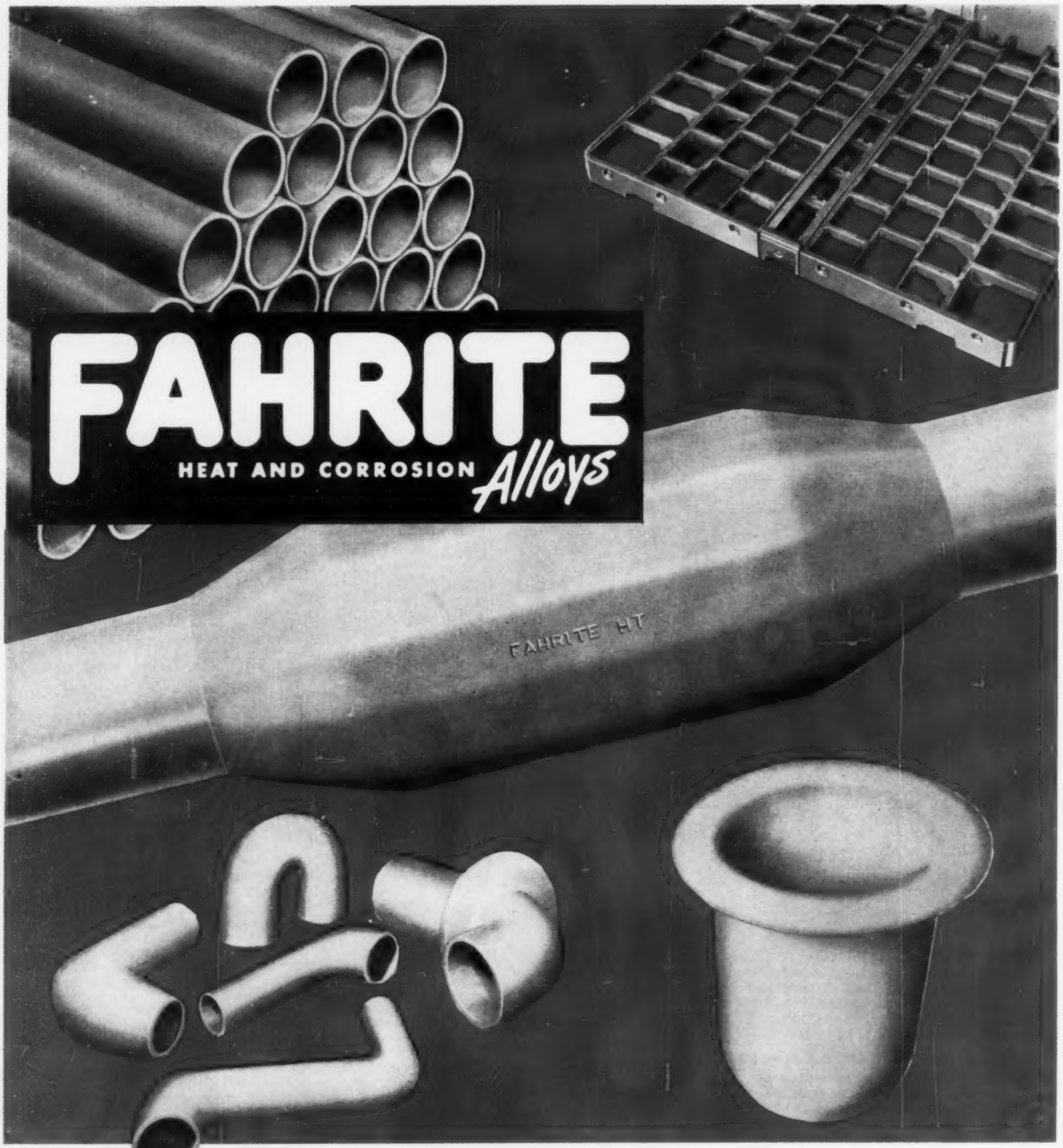
2036. Corrosion
Pamphlet discusses 15-lesson course on corrosion available through *A.S.M. Metals Engineering Institute.*

Tooling

2038. Composite Powders
Clad powders with metal and nonmetal cores open the way to new materials and technologies. Send for booklet "Metal and Composite Powders", *Sherritt Gordon Mines Ltd.*

2039. Electro-Hydraulic Forming
Brochure prepared by *General Dynamics Corp.* explains safe, efficient, compact, mobile "Hivopak" unit which operates indoors and provides the advantages of conventional explosive forming with none of the hazards and complications.

To request any item listed circle appropriate number on Reply Card, p. 48-B



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2040. Slide-Rule Calculator
Latrobe Steel Co. will send you a slide rule price estimator and weight calculator for the company's line of high-speed tool steels and die steels.

2041. Tool Steel Guide
Written by B. L. Averbach of M.I.T., "Tool Steels", a basic guide to the use of tool and die steels, has been published by *Climax Molybdenum Co.*

2042. Tool Steel Identification
The *Gorham Tool Co.* has published their eighth edition of a 26-page booklet covering classifications and symbols for identification of high-speed steels.

2043. Solid Lubrication
The theory and practice of solid lubrication is discussed in 8-page brochure published by *Alpha-Molykote Corp.*

2044. Iron Powders
Data Bulletin No. 3 from *Alan Wood Steel Co.* gives details on copper-carbon additives to iron powders.

2045. Rubberized Abrasives
These materials are used in delicate and sensitive deburring, smoothing, cleaning and polishing applications. 22-page application manual from *Cratex Mfg. Co.*

2046. Tungsten Steel
For the severe requirements of cutting tools, whether in tungsten carbide or in high speed steel, tungsten is indispensable. Booklet prepared by *Molybdenum Corp. of America* discusses successful applications.

2047. Colloidal Dispersions
Increased film coverage enables *Acheson Colloids Co.* to supply both quality as well as greater economy in colloidal dispersion applications. Pamphlet available.

2048. Industrial Band Saws
Armstrong-Blum Mfg. Co. will send details on "Marvel" line of industrial band saws.

Heating

2050. Optical Pyrometers
When control of high temperature is critical, rely on "Pyro-Eye", an automatic two-color optical pyrometer. Bulletin 613, *Instrument Development Laboratories, Inc.*

2051. High-Temperature Furnace
Literature describes laboratory furnace used in mechanical testing refractory metals at temperatures up to 4000° F. and at pressures less than 0.2 micron. *Marshall Products Co.*

2052. Temperature Measurement
Bulletin R-1034T discusses "Thermodot" unit for measuring and controlling temperature without contact. Unit sees small areas down to 0.080 in.; precision is 0.06%. *Radiation Electronics Co.*

2053. Open-Coil Process
Lee Wilson Engineering Co. has prepared a pamphlet on open-coil annealing which produces better drawing quality steel with uniform hardness throughout entire coil.

2054. Continuous Annealing Furnace
Bulletin B-81 from *Drever Co.* describes continuous annealing furnace which provides complete exposure of the strip surface to heat and furnace atmosphere and yet guarantees an unmarked surface after processing.

2055. Fluidized Bed
Alexander Saunders & Co. has released pamphlet discussing applications and operating details of "Saunders" fluidized-bed furnace.

2056. Heat Treating Costs
Pittsburgh Commercial Heat Treating Co. has released a booklet "The Cost of Heat Treating" which will assist companies now doing their own heat treating to establish the cost of this operation.

2057. Heat Treating Chart
Tempil Corp's four-color chart, "Basic Guide to Ferrous Metallurgy", illustrates forging, burning, annealing, transformation, stress relieving, nitriding, blue brittle, normalizing, and carburizing ranges, as well as grain size changes vs. temperature.

2058. Box Furnaces
Blue M Electric Co. will send literature discussing box-type furnaces for research and industrial use; temperature ranges to 2800° F.

2059. Pyrometer Accessories
A definitive book on thermocouples and pyrometer accessories is 56-page "Buyers' Guide and Users' Manual" prepared by *Bristol Co.*

2060. Chromel-Alumel
36-Page catalog-manual contains information on "Specification 3G-220" Chromel-Alumel wires as well as the complete family of Chromel-Alumel thermocouple, lead-wire and mechanical grade alloys. *Hoskins Mfg. Co.*

2061. Industrial Furnaces
The Electric Furnace Co. will send information on industrial heat treating furnaces built to your specific and individual requirements.

2062. Radiant Tubes
Wrought-cast radiant tubes give consistent long life. Additional information from *General Alloys Co.*

2063. Atmosphere Box Furnace
Bulletin 1096 explains "Model RB-45" atmosphere box furnace suitable for a wide range of heat treating applications at all heat levels up to 2000° F. where atmosphere is required. *Lindberg Engineering Co.*

2064. Low-Temperature Cabinets
Folder from *Revco Inc.* describes low-temperature cabinets, in capacities from 1½ to 6 cu.ft., which provide temperatures to −140° F.

2065. Reciprocating Hearth Furnace
Rotary retort and reciprocating hearth furnaces are best for all small parts heat treating; capacities to 800 lb. per hr. Catalog from *American Gas Furnace Co.*

2066. Furnace Retorts
Pamphlet issued by *Pressed Steel Co.* tells about light-wall construction used in fabricating furnace tubes and retorts.

2067. Refrigeration Units
Data sheets and catalog explain "cascade" refrigeration systems for low temperature industrial applications. *Harris Mfg. Co.*

2068. Thermocouples
Catalog G100-4 sets forth the advantages of "MegopaK" small diameter, mineral-insulated thermocouples. *Minneapolis-Honeywell.*

2069. "Heat Treat Review"
Contains discussion of new developments in high-temperature gas carburizing, including heating curves, photomicrographs of test samples, and illustrations of carburizing equipment (Vol. 11, No. 2). *Surface Combustion Div.*

2070. Induction Heating
56-page catalog from *Induction Heating Corp.* presents complete line of induction heating equipment for hardening, brazing, soldering, forging, annealing, melting, sintering, welding, refining, shrink fitting, and crystal growing.

2071. Continuous Annealing
Surface Combustion Div. will send literature on a continuous annealing furnace which has carburizing, carbonitriding, skin recovery, annealing, and spheroidizing capabilities.

2072. Furnace Fans
Furnace fans from *Stanwood Corp.* are statically and dynamically balanced for longer service life. Literature available.

2073. Homogenizing Furnaces
Direct gas-fired homogenizing furnaces operating up to 1150° F. are used to prepare aluminum ingot for extrusion. Production is increased, extrusion tear marks are reduced. Bulletin 100HZ, *Despatch Oven Co.*

2074. Tool Steel Furnace
Data sheet FEC-1 describes "No-Muffle" furnace for treating high-speed steels; temperatures to 2350° F. *C. I. Hayes, Inc.*

2075. Quenching Information
E. F. Houghton & Co. has prepared 70-page book which contains authoritative data on quenching materials and techniques.

2076. Temperature Potentiometer
Leeds & Northrup will send Data Sheet E-33 (5) which describes "Model 8695" temperature potentiometer, a portable instrument with a selection of 15 different temperature ranges.

2077. Salt Bath Furnaces
Lindberg Engineering Co. has literature describing complete line of Lindberg-Upton salt bath furnaces for hardening high-speed tool steels.

2078. Temperature Indicators
"Thermomelt" temperature indicators are the quick, precise way to determine temperatures; accurate to within 1%; measuring range, 113 to 2000° F. Details from *Markal Co.*

2079. Industrial Thermocouples
48-page catalog TC-16 illustrates complete line of "Ceramo" thermocouples to measure temperatures from −450 to +4000° F. *Thermo Electric Co.*

2080. Induction Heating Unit
Induction heating equipment is the most practical and efficient source of heat for industrial applications. Catalog from *Lepel High Frequency Laboratories.*

Finishing

2082. Electroless Nickel Plating
Enthone, Inc. has published a pamphlet on "Enplate Ni-410" chemical nickel plating bath which deposits a uniformly thick, hard, corrosion-resistant nickel plate without the use of an electric current.

2083. Conversion Coating
The "Paintite" process cleans and phosphates simultaneously. Folder discusses Paintite and ten other "Turcoat" phosphating and conversion coating processes. *Turco Products, Inc.*

2084. Cleaning and Phosphating
Put a complete cleaning-phosphating department in your plant at a fraction of the cost and space of standard systems. Details on "Phosteem" system from *Amchem Products, Inc.*

To request any item listed circle appropriate number on Reply Card, p. 48-B

Huntington Alloys

INCOLOY Alloy 800—a low cost alloy that offers good strength along with good resistance to corrosion and oxidation . . . even at elevated temperatures

Ductile, austenitic alloy resists "sigma phase" embrittlement in the critical 1100 to 1600°F range . . . resists carburization . . . resists distortion due to thermal stresses

Because of its excellent corrosion and oxidation resistance, INCOLOY* alloy 800 is a highly dependable alloy for applications involving high temperatures under corrosive conditions such as in the heat treating industry—baskets, trays, muffles, radiant tubes, etc.; the chemical and petroleum process industries—reformer and cracker tubes, flare tips; and the home appliance field as sheathing for electrical resistance heating elements.

High Temperature Properties

INCOLOY alloy 800 offers high tensile and fatigue strength, good impact strength and good corrosion resistance at high temperatures. Its relatively low coefficient of expansion combined with its high yield strength provide good resistance to thermal stresses.

Oxidation Resistance

The high nickel and chromium contents of INCOLOY alloy 800 impart high resistance to oxidation and scaling at high temperatures. This resistance is related to the tightly adherent oxide film that is formed which helps protect the surface from progressive oxidation.

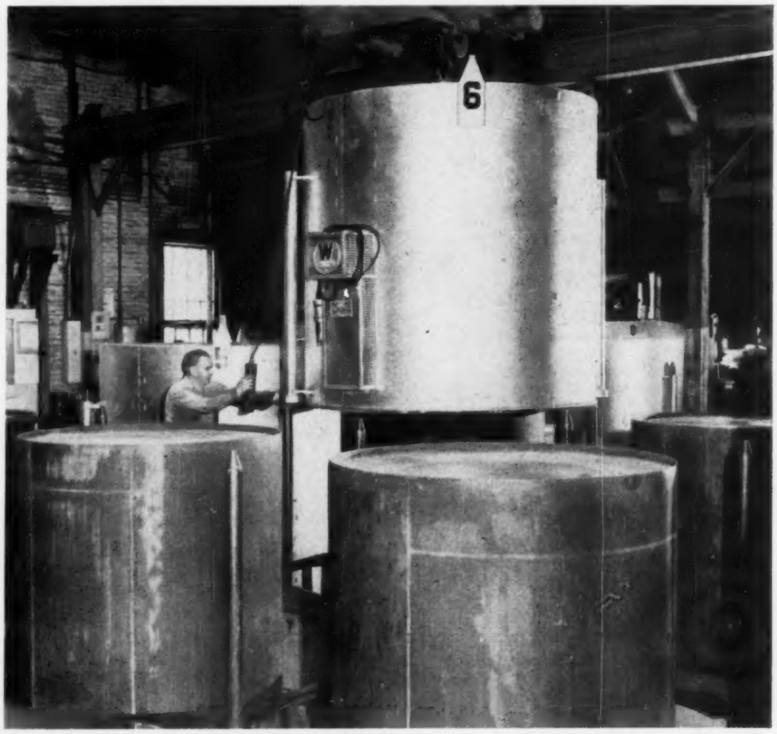
Carburization Resistance

INCOLOY alloy 800 has excellent resistance to the absorption of carbon. Consequently, the alloy is widely used under carburizing conditions.

For the complete story on INCOLOY alloy 800, write the Huntington Alloy Products Division for a copy of new technical bulletin T-40, "Engineering Properties of INCOLOY alloy 800."

*Registered trademark

HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
Huntington 17 INCO West Virginia



Like new after two hot years, the annealing hood at center was fabricated from INCOLOY alloy 800 sheet. Alloy 800 has many proved advantages in heat-treating equipment—may be the answer to difficult metal problems in other fields.

RUPTURE STRENGTH OF INCOLOY Alloy 800 EXTRUDED TUBING

TEMPERATURE °F	STRESS (PSI) FOR RUPTURE IN					
	1000 HOURS		10,000 HOURS**		100,000 HOURS**	
	LOG-LOG	PARAMETER	LOG-LOG	PARAMETER	LOG-LOG	PARAMETER
1200	23,500	18,000	20,000	11,000	17,000	7,800
1300	. . . . . .	10,800	. . . . . .	7,400	. . . . . .	5,100
1400	8,000	7,400	6,000	5,000	4,400	3,400
1500	. . . . . .	5,000	. . . . . .	3,400	. . . . . .	2,250
1600	3,800	3,500	2,700	2,300	1,900	1,500
1700	2,200	2,400	1,500	1,550	1,000	1,100
1800	1,700	1,700	1,150	1,200	780	820
1900	1,250	1,225	850	860	580	600
2000	1,050	920	. . . . . .	670	. . . . . .	. . . . . .

** EXTRAPOLATED

INCOLOY® NICKEL-IRON-CHROMIUM ALLOYS

2085. Chemical Milling
Eastman Kodak Co. has released booklet, "Etching, Chemical Milling and Plating With Metal-Etch Resist".

2086. Selective Plating
Selectrons, Ltd. has released folder explaining "Selectron" plating process and several new powerpacks for "table-top" electroplating operations.

2087. Electrocleaner
Pamphlet presents data on "Oakite 190" a reverse-current cleaner that removes oily soils, smut and rust bloom which normally require additional treatment. *Oakite Products, Inc.*

2088. Zinc Barrel Plating
R. O. Hull and Co. will send information on "Rohco Econobrite", a zinc brightener which features broader latitude of operating conditions at minimum cost.

2089. Chromium Chemicals
Solvay Process Div. will send 80-page bulletin "Chromium Chemicals" which discusses mutual chromic acid and the "Mutual" line of chromium chemicals . . . uses, properties and other technical data.

2090. Blast Cleaning
"Rotoblast" equipment provides complete automation in blast-cleaning operations—cleans up to 45,000 castings per shift. Information from *Pangborn Corp.*

Welding

2092. Tungsten Carbide Powder
Data sheet No. T-5 tells about "Colmonoy No. 75" tungsten carbide hardsurfacing "sprayweld" powder for producing wear-resistant welded overlays. *Wall Colmonoy Corp.*

2093. Brazing Alloys Chart
American Brazing Alloys Corp. has released a comparison chart listing A.W.S., A.S.T.M. and manufacturer's designations for all important silver, copper and brass-base brazing alloys.

2094. Welding and Brazing
50-page catalog and instruction manual covers welding, brazing, soldering and fluxes. Properties uses and application data included. *All-State Welding Alloys.*

2095. Welding Guide
"Vest Pocket Guide to Better Welds", 80-page booklet published by *Hobart Brothers Co.*, gives data on proper welding procedures and techniques, causes and cures of welding troubles, welding symbols, electrodes, definitions, joints, wires and fluxes, and power sources.

2096. Welding Symbols Chart
If you are interestd in design, development, or manufacturing where welding is used, a welding symbols chart prepared by *Lenco, Inc.*, will be of value to you.

2097. Silver Brazing
Silver brazing is the precise tool for precision joining operations. Bulletin 20 explains many "Easy-Flo" brazing applications. *Handy & Harman*

2098. Indium Solders
"Indalloy" intermediate solders used in printed circuit work have good wetability, corrosion resistance, flowability and workability. Booklet from *Indium Corp. of America*

2099. Plasma Spraying Process
Brochure 101 explains the plasma spraying process and applications in high-temperature protection, fabrication of parts of "unworkable materials" and deposition of carbide hardfacing. *Plasma Systems Corp.*

2100. Stress Relieving of Welds
32-page booklet answers many of the questions about why, when and what to pre-heat and stress relieve. Booklet EW-249 from *Hobart Brothers Co.*

2101. TIG Welding Guide
A new guide designed to assist welders in the proper use of tungsten electrodes has been published by *Sylvania Electric Products.*

2102. Silver Brazing Alloys
Select a brazing process tailored to your precise requirements from complete line of "Silvaloy" low-temperature silver brazing alloys and fluxes. Literature from *American Platinum & Silver Div.*

Testing

2104. X-Ray Microscope
8-page folder entitled "Isolation of Selected Elements With an X-Ray Projection Microscope" has been reprinted by *Phillips Electronic Instruments.*

2105. Electrolytic Polisher
The "Jena" electrolytic polisher is the only instrument in the world permitting constant observation of the etching process. Data from *Ercona Corp.*

2106. X-Ray Unit
The "Baltospot 150" industrial x-ray unit will penetrate 1⅝ in. of steel and

Circle appropriate number on Reply Card, p. 48-B

permits 360° radiography. Information from *Westinghouse*

2107. Universal Tester

Pamphlet RU-2-60 from *Riehle Testing Machines Div.* reviews the capabilities of a universal testing machine. Available with complete instrumentation for testing materials over a wide range of environmental conditions.

2129. Metallographic Camera

The "Model L" camera takes the load off your busy metallograph. Catalog E-210 from *Bausch & Lomb.*

2130. Superficial Tester

The "TwinTester" combines in one instrument the functions of a Rockwell and a "superficial" hardness tester. Catalog RT-58 from *Wilson Mechanical Instrument Div.*

2131. Testing Machines

4-page Bulletin G-361 illustrates line of testing machines for Brinell hardness, ductility, tensile, compressive, transverse and strength; also hydrostatic and pneumatic machines, proving rings, calibration presses and special testing machines. *Steel City Testing Machines*

2132. Research Activities

30-page booklet covers *General Mills* extensive research activities in the physical sciences — electron and surface physics, ion and plasma physics, chemistry and materials, and electrohydrodynamics.

2133. Specimen Mounting Material

The Fulton Metallurgical Products Corp. has published a brochure describing "Quickmount", a fast-setting, self-curing specimen mounting material that produces clear mounts without application of heat or pressure.

2134. Portable Brinell Testers

The "King" portable hardness tester provides accuracy, portability and economy. Brochure from *King Tester Corp.*

2135. Listing of Test Machines

Testing Machines, Inc. has prepared a 20-page list of testing machines for all industries. A total of 461 testing machines is covered in 69 testing categories.

2136. Metallurgical Microscope

William J. Hacker & Co. will send leaflet describing the extremely compact "Reichert Metatest", a metallurgical microscope of great versatility.

Casting

2138. Vacuum Slide Calculator

F. J. Stokes Corp. will send free vacuum slide calculator as well as information on "Series H Microvac" pumps, the most advanced in their class.

2152. Endothermic Generator

The "Hyen" endothermic generator is a fully automatic process for producing low-cost protective atmospheres used in bright hardening, bright annealing or bright brazing of steel. *Lindberg Engineering Co.*

2153. Aluminum Furnace Refractories

8-page reprint describes developments of refractories for use in aluminum melting furnaces. *Harbison-Walker Refractories*

2154. Casting Specifications

The *Steel Founder's Society of America* has released a revised edition of "Summary of Steel Castings Specifications".

2155. Insulating Firebrick

Catalog R-33 from *Babcock & Wilcox Co.* contains complete information on lightweight insulating firebrick.

2156. Hydrogen Sulfide Units

Girdler Corp. has prepared a publication explaining units for the economical production of hydrogen sulfide gas at rates from 1 to 5 tons per day.

Parts

2158. Bearing Terminology

24-page booklet "Bearing Parts and Nomenclature of Standard and Precision Bearings" defines and illustrates bearing parts and terms. *SKF Industries, Inc.*

2159. Hydraulic Tubing

Bulletin 39 summarizes information on small-diameter hydraulic tubing for operating pressures up to 3000 psi. *Superior Tube Co.*

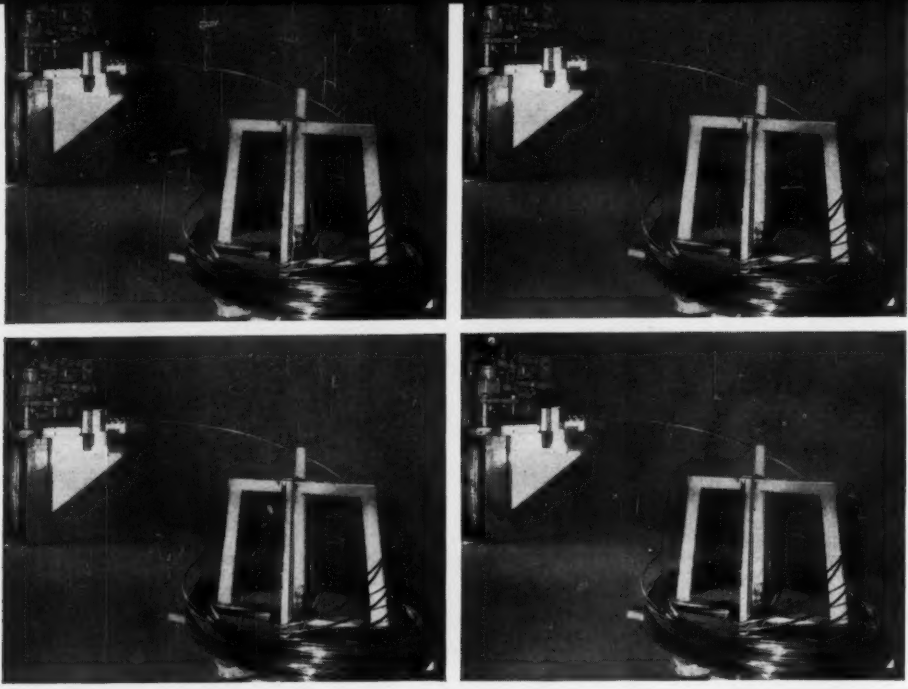
2160. Wire Cloth

120-page brochure illustrates wire cloths made with standard alloys as well as unusual metals such as titanium, silver, Hasteloy C, platinum, lead, stainless steel or bronze. *Cambridge Wire Cloth Co.*

2161. Welded Steel Tubing

Ohio Seamless Tube Div. has released a pamphlet describing welded steel tubing for mechanical and pressure applications.

Circle appropriate number on Reply Card, p. 48-B



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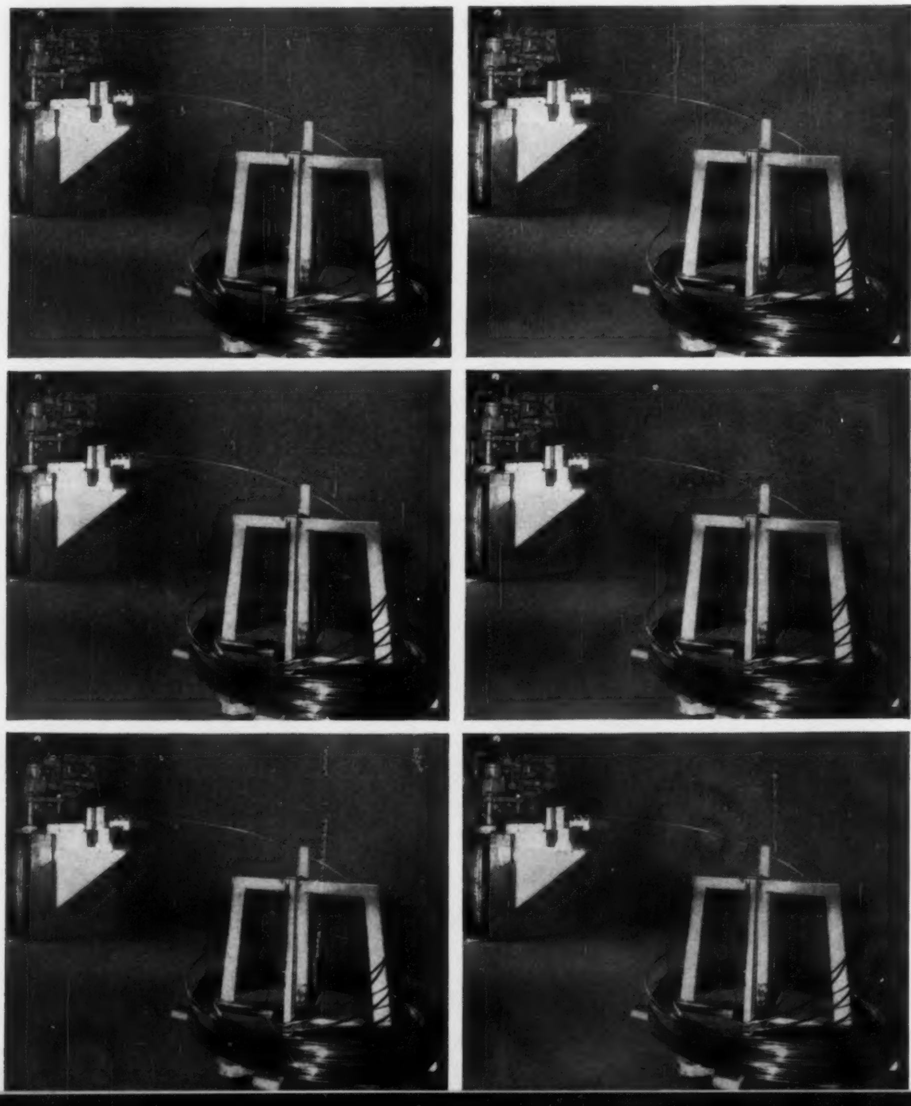

Circle 2238 on Page 48-B

First in our laboratories, NOW FROM THE FIELD excellent performance reports on this new Vanadium-Alloys high speed steel...

VASCO Hypercut®

Vasco HYPERCUT, tested widely throughout the country under designation B-1426, is now available for the general market. Because this remarkable new steel hardens to 70 Rockwell C, you'll find it easy to harden regularly to performance peaks of 68-69. Vasco HYPERCUT is recommended for machining superalloys and heat-treated steels. Available in tool bits, bars, forgings, drill rod, sheet, plate and circles. Details on request.

Metal Producer

Type of test—BREAKDOWN TEST TURNING INCONEL 700

Grade	*Length of Cut*	*Tool Life*
VASCO HYPERCUT	18″	90 minutes
	Second Test	
VASCO HYPERCUT	23″	115 minutes
A competitive high hardness high speed steel	15½″	77½ minutes

Toolmaker

Type of test—CUTTING SLOTS IN SHAFTS HEAT-TREATED TO ROCKWELL "C" 36/44

VASCO HYPERCUT doubled the production of carbide tools and triples the production of M-4 tools.

Large Forging Company

Type of test—LATHE TURNING ON INCONEL 901, V-57 and titanium metals

VASCO HYPERCUT operated a full lathe hour shift on two resharpenings as against four regrinds with super high speed steel.

Midwest Aircraft Manufacturer

Grade	SPEED (SFM)	TOOL LIFE (MIN.)	METAL REMOVAL (cu.in.)	COST per Cubic Inch
VASCO HYPERCUT	22	60.0	13½	$0.62
Brand S-1	22	27.0	6½	.88
Brand R-1	22	5.1	1	2.31
VASCO HYPERCUT	35	13.0	4-8/10	0.77
Brand S-2	35	3.7	1½	2.06
Brand R-2	35	.94	½	4.81
VASCO HYPERCUT	35-24	38	3½	0.75
Brand S-3	35-24	1.84	1¾	1.64
Brand R-3	35-24	1.25	1½	2.01

Tool Manufacturer

Type of test—END MILLS ON A SPECIAL CUTTING TEST SETUP

VASCO HYPERCUT performed 80% better than Brand A high hardness high speed steel, 50% better than Brand B high hardness high speed steel and 200% better than M-34 high speed steel.

FIRST QUALITY TOOL & SPECIAL STEELS

VANADIUM-ALLOYS STEEL COMPANY

GENERAL OFFICES: LATROBE, PA.

DIVISIONS: Anchor Drawn Steel Co. • Colonial Steel Co. • Metal Forming Corporation • Pittsburgh Tool Steel Wire Co. • Vanadium-Alloys Steel Co.

SUBSIDIARIES: Vanadium-Alloys Steel Canada Limited • Vanadium-Alloys Steel Societa Italiana Per Azioni • EUROPEAN ASSOCIATES: Societe Commentryenne Des Aciers Fins Vanadium-Alloys (France) • Nazionale Cogne Societa Italiana (Italy)

Circle 2239 on Page 48-B

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

December, 1961 Issue
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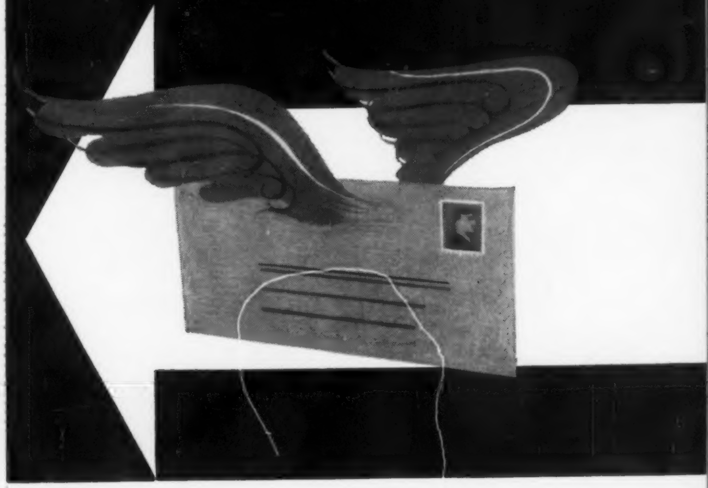

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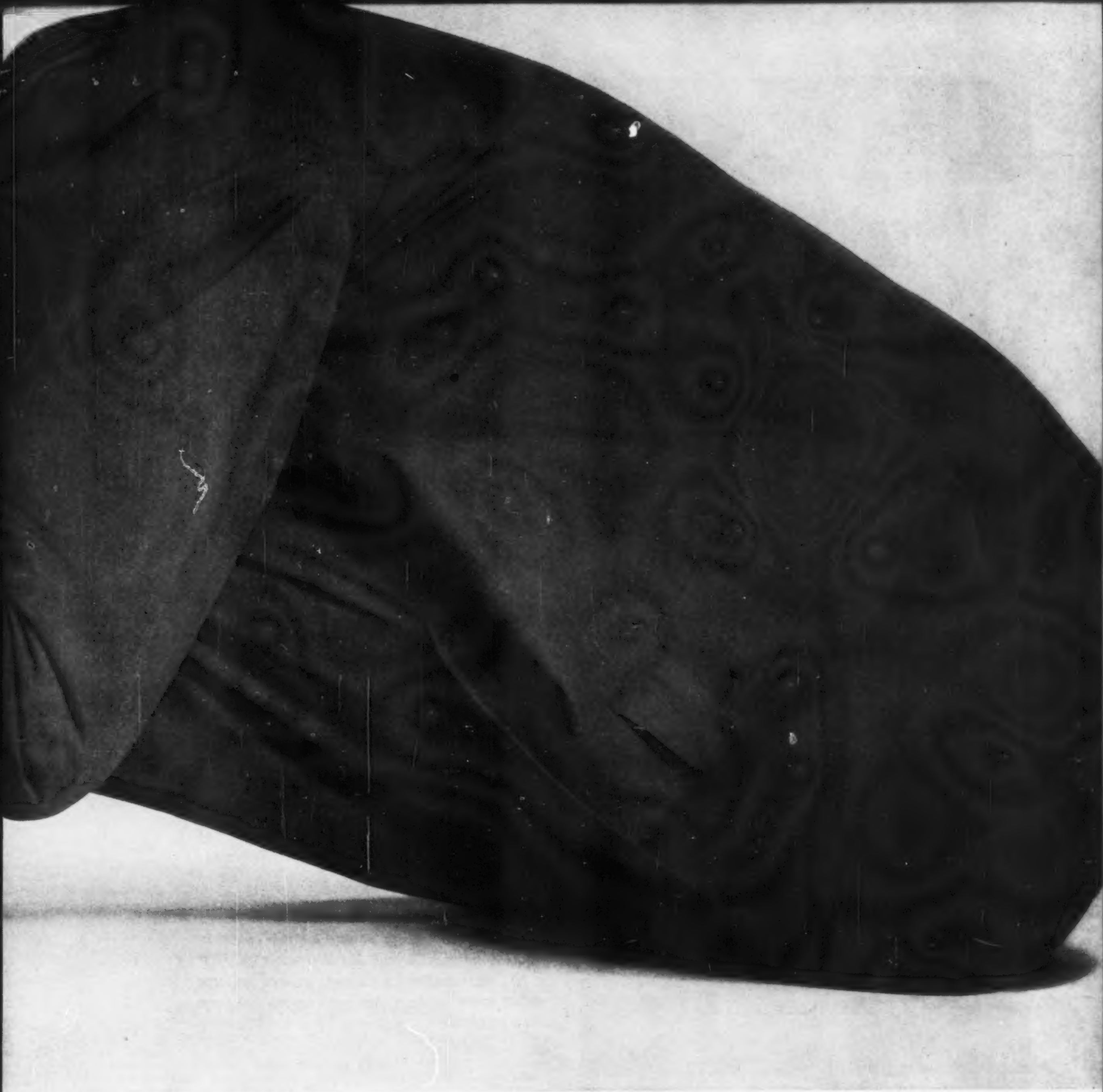
Please Include Your Name and Address!

Don't get boxed in by oxygen supply problems...

Keep your steel operations flexible by removing all uncertainties about oxygen supply with an Airco tonnage oxygen plant. A plant we build and operate for you — on or adjacent to your site — gives you assurance of supply that only an experienced oxygen producer like Airco can guarantee.

GUARANTEED BACK-UP. Your oxygen plant is backed up by Airco's nationwide network of oxygen plants. If the plant is down for any reason, Airco will keep your oxygen flowing from its integrated system. If you need more oxygen than originally anticipated, Airco will supply whatever quantities you require. And you won't be boxed in with a rigid purchase arrangement that can't be adjusted to steel production.

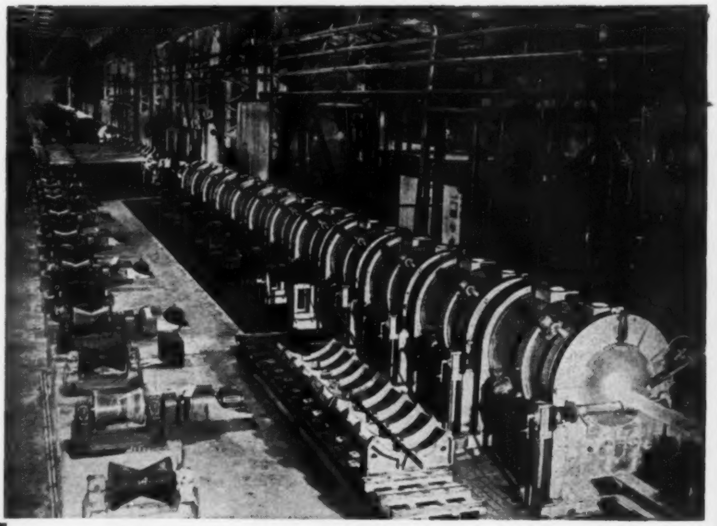
PROVEN TECHNOLOGY. Making oxygen — like making steel — is a specialized business. Airco has 45 years'

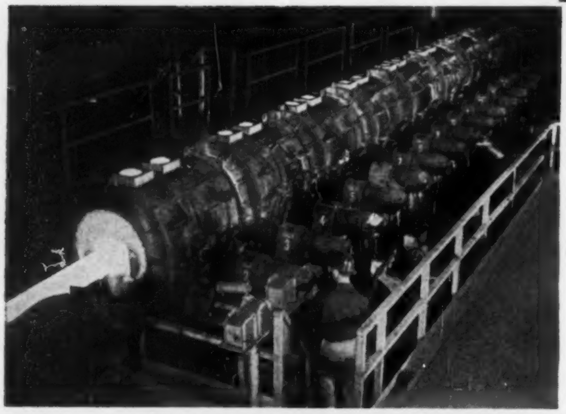


NEW SLANTS ON HEAT PROCESSING FROM SELAS

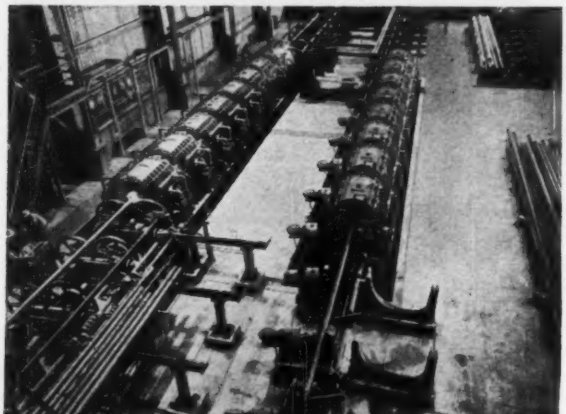
Here's how the Steel Industry relies

TUBING... *is normalized and, if required, stretch-reduced in this Selas barrel-furnace line. After forming and welding, the tubing is conveyed through a 48-barrel normalizing line with exit temperature approximately 1650° F. Stretch-mill product proceeds through 12 additional* GRADIATION® *furnaces which heat tubing to 1800°-1850° F. Entire process is automated, with line speeds matching mill speeds.*





BLOOM REHEATING "*on the fly," at rates of 198 tons per hour is accomplished in this continuous Selas barrel-furnace line. Reheating time of* only 3 minutes *reduces scale, amounting to a saving of 3 tons of steel per hour. Automated handling saved enough to pay for equipment in first 1½ months! Occupying floor area only 63' x 11', this continuous furnace assures uniform rolling temperature within each bloom and from piece to piece.*



SHORT-CYCLE HEATING *of seamless tubing for oil-country application is a typical cost-saving operation for Selas barrel-furnace lines. This overall view shows hardening (left) and tempering (right) lines, with automatic transfer between these treatments. Eight barrels per line. Advantages include: uniform properties throughout, negligible scale, reduced floor space requirements, and high degree of controllability.*

on Selas barrel-furnace lines

The installations on these pages graphically demonstrate how the steel industry relies on Selas barrel-furnaces to

- cut operating costs
- increase production rates
- reduce handling and labor requirements
- save valuable floor space
- improve product quality

Specifically designed and custom-built to meet individual production requirements and job specifications, Selas barrel-furnace lines employ time-proven standardized engineering features for long-time operating dependability and minimum initial investment. Acceptance? 446 Selas barrel-furnaces are at work in 49 separate heat treating lines for a variety of continuous applications including annealing stainless bars and tubing, heating billets for piercing, reheating pierced tubes for sizing, hardening and tempering oil country alloy and carbon tubing, etc. What's more, 96 additional units are now in various stages of construction.

At your convenience . . . without cost or obligation to you . . . a Selas field engineer would welcome the opportunity to survey your needs. For this personal service contact our Furnace Steel Mill Division, Dresher.

SELAS CORPORATION OF AMERICA
312 Dreshertown Road, Dresher, Pa.

EUROPEAN SUBSIDIARY: Selas Corporation of America, European Div., S.A., Pregny, Geneva, Switzerland. **INTERNATIONAL AFFILIATES: AUSTRALIA**—Major Furnace and Combustion Engineers Pty, Ltd., Melbourne; **FRANCE**—Societe Exploitation de Produits Industriels, Paris; **JAPAN**—International Machine Co., Ltd., Tokyo.

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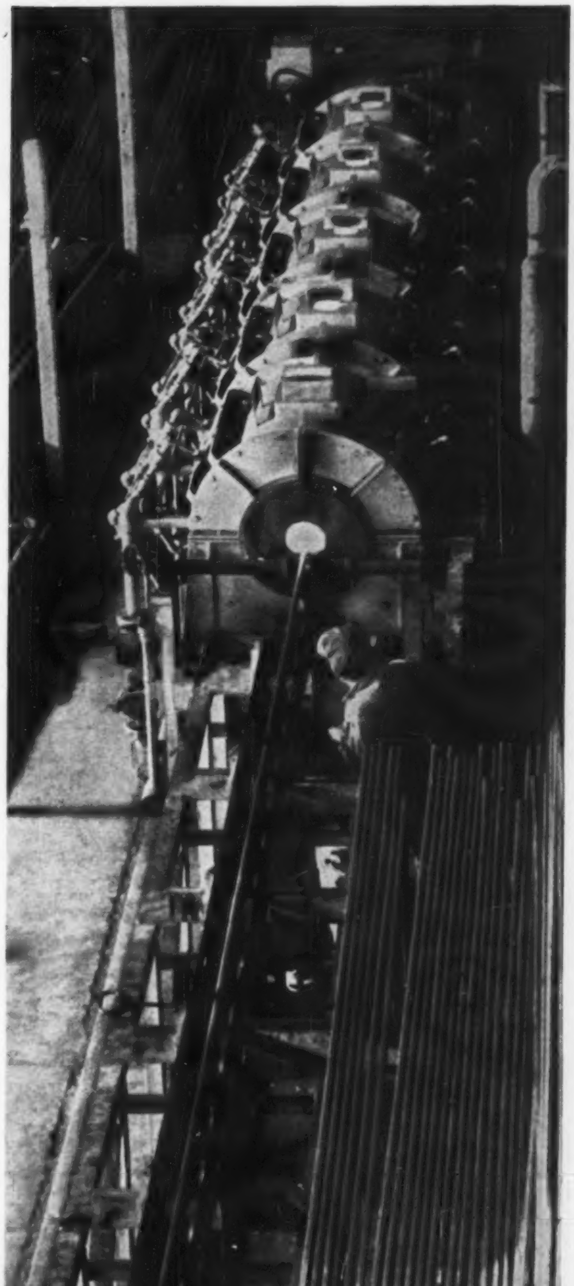


STAINLESS STEEL *bars up to 5¼" cross-section and lengths to 30' are continuously annealed, and other grades normalized in this compact line of barrel-type furnaces. DURADIANT® burners heat uniformly at high thermal gradient without flame impingement on the work, resulting in minimum oxide formation. Annular ring water-spray quench cools work quickly and uniformly for maximum straightness in the annealed product.*

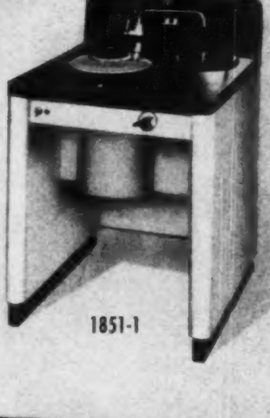
SELAS

HEAT AND FLUID PROCESSING ENGINEERS
DEVELOPMENT / DESIGN / CONSTRUCTION

Polimet

A NEW NAME IN METALLOGRAPHIC POLISHERS

- VARIABLE SPEED—100-1200 r.p.m.
- QUIET OPERATION
- VIBRATION FREE
- EASY CONTROL
- HIGH TORQUE—½ h.p.
- AVAILABLE IN 1, 2 or 3 UNIT TABLES
- INTERCHANGEABLE BALANCED WHEELS
- VITREOUS FINISHED, EASY TO CLEAN BOWL

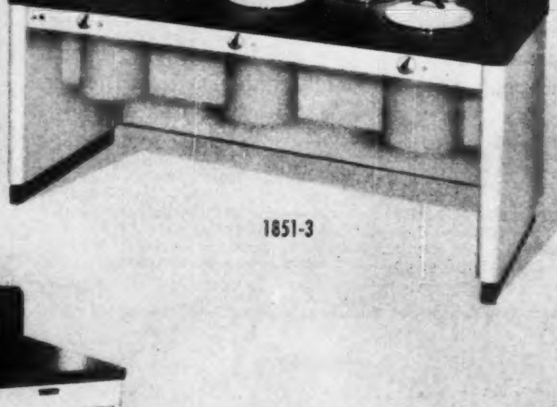


1851-1

1851-2

With infinitely variable speed over a wide range it is possible for the operator to select the exact speed desired for the particular sample at hand. The complete speed range is controlled by turning a knob. No cranking is required to change speed, no belts, pulleys or mechanical clutches are used, eliminating the source of most vibration present in other variable speed polishers. The electronic control is accomplished through the use of only one vacuum tube and the complete electronic circuit is mounted on a 4" x 4" panel easily accessible on the outside of the motor.

The 1851 Polimet series is furnished in the Buehler steel polishing tables, finished in silver gray hammertone. The top and edges of the table are black formica. One, two, or three unit tables are available.



1851-3

1851-2, 1512-2, 1512-3, 1514

Buehler Ltd.

METALLURGICAL APPARATUS

2120 GREENWOOD ST.,
EVANSTON, ILLINOIS, U.S.A.

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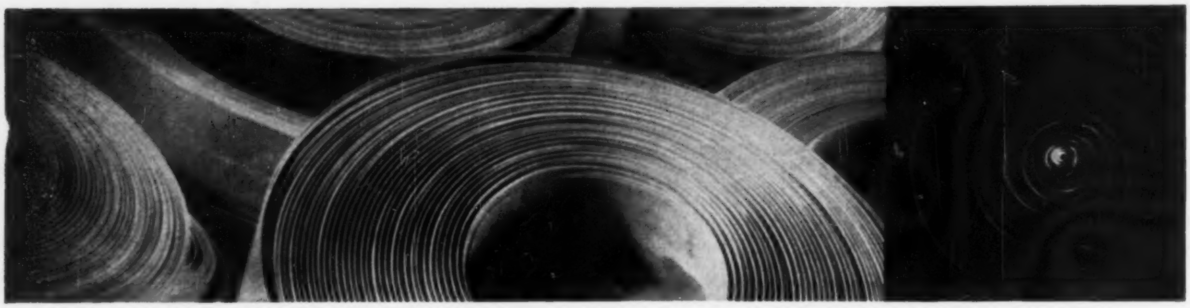
 Circle 2166 on Page 48-B

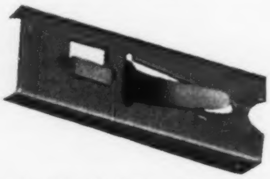


How they're using

Wallace Barnes Cold-rolled Specialty Steels

1. *In Three Drawing Stations*

The part shown in illustration one was made from .59 – .74% carbon steel in three drawing stations. From .70 – .80% carbon, this piece should have four or five drawing stations. The piece could be made from .90 – 1.05% carbon, but would require seven drawing stations with fully annealed steel.



2. *Blanked on 45° Angle*

The stamping shown in the second illustration was made from .70 – .80% carbon spring steel. It was blanked and pierced on a 45° angle, with small holes pierced to prevent fracture in later forming and bending. It was then given severe secondary forming. The small tab shows "orange peel" and probable fracture would occur if the part were formed from .90 – 1.05% carbon.

3. *All Flanging One Operation*

Our third part is a gun stamping made from .70 – .80% carbon with a sharp bend with the grain in one stroke of the press. Higher carbon will fracture due to its less ductile qualities.

4. *Thirteen Steps Progressive*

The fastener shown in the fourth illustration was made from the .59 – .74% carbon steel, the only spring steel which would take the bends and draws to which it is subjected here. All the higher carbon steels were rejected because they failed under the cold-work necessary to produce the two small extrusions. It took seven reductions to bring these extrusions within tolerance. There were thirteen steps total in the progressive die.

These examples show how proper steel selection may save operations and insure satisfactory performance. Among the many sizes and types of Wallace Barnes cold-rolled specialty steels is the right one for your application.

Send for brochure illustrating various types of products made from Wallace Barnes Specialty Steels.

Wallace Barnes Steel Division

Associated Spring Corporation

Bristol, Connecticut

Circle 2167 on Page 48-B

Metals are *born* in refractories. And most new ideas in metallurgy call for a new idea in refractory science . . . because a metal can be only as good as the refractory which contains it. Norton makes the finest.

The crucible of the reduction bomb, where uranium and plutonium burst into being, is a Norton product, pure magnesium oxide.

Another Norton material, fused stabilized zirconia, makes possible electric furnacing for processing tungsten and molybdenum, at temperatures up to 2200°C. Zirconia also lines huge pebble heaters and air furnaces in which metals for missiles are tested.

More super-alloys for missiles, submarines and space vehicles are possible through new vacuum melting techniques with high purity fused magnesia made by Norton. And in the aluminum industry, new efficiencies are being achieved with reduction cell linings of silicon carbide and cathode bars of titanium diboride.

In metallurgy as in other fields, Norton is crystallizing ideas into products to solve many problems . . . through oxide fusion and in probing experiments in carbides, nitrides and borides. Norton is ready to work with you in engineering materials to meet your needs. Write NORTON COMPANY, Refractories Division, 331 New Bond St., Worcester, Mass.

NORTON

REFRACTORIES

Crystallizing ideas into products

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Circle 2170 on Page 48-B

Circle 2171 on Page 48-B

Fights Flux Attack to Cut Brazing Costs

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Circle 2173 on Page 48-B

from Ryerson

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METAL PROGRESS
THE MAGAZINE OF MATERIALS AND PROCESS ENGINEERING
Vol. 80, No. 6 December 1961

GUEST CRITICAL POINT

H. W. McQuaid
Consultant
Cleveland

Is 1700° F. the Only Temperature for Grain Size Control?

In metallurgical laboratories throughout the country, technicians pack steel specimens in carburizing boxes and heat them for 8 hr. at 1700° F. When these specimens are polished, etched and examined with a microscope, the grains outlined by Fe_3C in the case indicate whether the steel is "fine-grained" or "coarse-grained". To me, this procedure seems somewhat futile. After all, most of these steels, particularly the medium-carbon grades which are heat treated, will be austenitized at 1600° F., a temperature at which virtually all steels are fine-grained even though they may or may not be coarse-grained at 1700° F. Unless the steels are to be carburized, it would appear to be useless to specify this particular testing temperature. In fact, perhaps present grain-size specifications merit a critical appraisal, and some modification, as well. However, let us first see how it all began.

From Then Until Now

Actually, 1700° F. was selected as the testing temperature because we were working with the case-hardening grades, and that temperature permitted carburization. Further, it enabled heat treaters to eliminate heating at two temperatures, one to "refine the core", the other to "refine" the case.

With fine-grained carburizing steels, especially the alloy grades, engineers soon noticed that improved fractures and better dimensional control were obtained in heat treated parts which had been quenched only once after carburizing. As for specific treatments, parts were either quenched directly from the carburizing furnace, or were air cooled, reheated to a temperature which did not coarsen the case or core, and quenched.

As 1700° F. became accepted as the testing temperature for grain-size control, metallurgists observed that it was high enough to austenitize practically all alloy and carbon steel parts in practice. Thus, it freed the steelmaker and the heat treater from any worry as to the grain coarsening in practice. As a consequence, after these specifications for rating the grain size of carburizing grades had been accepted by large users of alloy steels, they were adopted for all alloy grades, and now are almost universally applied.

It would appear that the grain-size specifica-

Harry W. McQuaid (Left) and Erik W. Ehn, Co-Originators of the Grain Size Test Which Bears Their Names, Inspecting One of the Byproducts of It, the A.S.T.M. Grain-Size Chart

tion unnecessarily limits most heat treating grades. Since these restrictions also introduce serious drawbacks in steelmaking practices, it is my recommendation that very serious thought be given to changing the grain-size control temperatures to suit the particular steel composition and the final application for which it has been ordered. In other words, if the steel is to be austenitized at 1600 or 1550° F. for quenching and tempering, the grain-size control temperature should be associated with either of these temperatures rather than be arbitrarily fixed at 1700° F. In my opinion if this suggested technique is properly worked out, higher "shipped yields" would result, and hot-rolled surfaces would have fewer surface defects and require less conditioning.

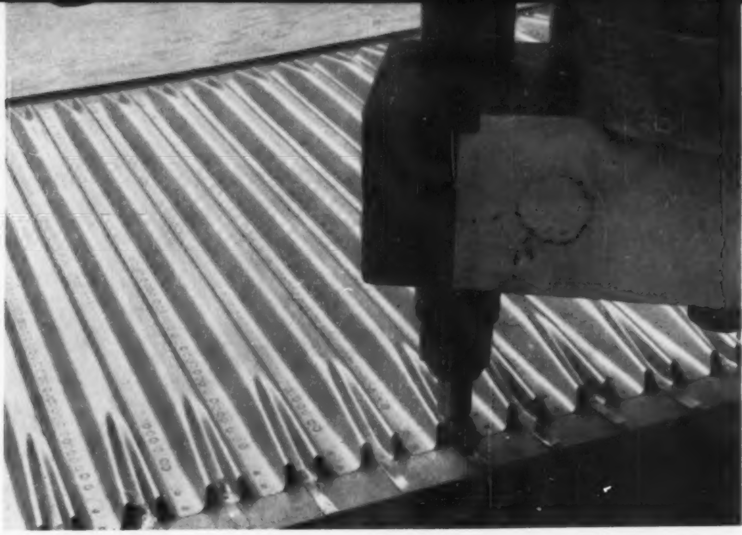
This could be done because aluminum, the agent usually added to control grain size in steel, could be limited to a definite minimum value. Aluminum directly affects sulfide types in that the critical amount needed to control grain size also results in grain-boundary sulfides which cause hot shortness during rolling. Since it is also a strong deoxidizer, aluminum combines with oxygen to form inclusions of Al_2O_3; these adversely affect transverse physical properties, tool life, bloom and billet surface and shipped yield.

In making 1600° F. the grain-size control temperature, the problem will be to keep the grain-coarsening range close to 1600° F. To do this, it becomes necessary to cut back the aluminum limit, perhaps increasing silicon, and using calcium-silicon, or some other deoxidizer. At any rate, the chief objective is to reduce the total aluminum addition to as close to zero as possible at tap time, and still have grain coarsening start just above 1600° F. In other words, the aim is to use the minimum amount of control reagents needed to meet the required coarsening temperature.

Improvement To Be Expected

If this program is worked out carefully, the steel industry should end up with a definite improvement in melting practices, and conditioning and inspection economics. Also the steel user (who has to machine and heat treat the material) should find the steel simpler and less expensive to handle. There would be, I feel, an immediate improvement in pouring practice, bloom and billet conditioning, with less loss in handling time, lower costs, and a definite increase in yield. When machining such material, the customer would notice improved surface finish, better tool life, and increased output from his production lines.

In my opinion, this project is important enough for the steel industry and the steel buyer to get together and set up an industry-wide research program to insure its proper completion. Though it undoubtedly involves many more problems than might appear from any brief study, it would be well worth the effort, the time, and the money spent on it.



Progress in High-Temperature Materials

René 41 Corrugated Substructure Is Being Welded to a Flat Skin Panel for Testing Under Conditions Imposed Upon Re-Entry Vehicles

How to Make Reliable Seam and Spot Welds in René 41

*By B. M. WAHLIN and D. R. COLES**

High-quality seam and spot welds in René 41 can be made consistently if precautions based on the metallurgical behavior of the alloy are taken into account. Mill-annealed sheet with fine grain structure and randomly dispersed carbides is preferred. Postweld cooling rate and initiation and magnitude of the forging force must be precisely controlled to avoid cracks. (K3; Ni-b, SGA-h)

Increasing demand for welded structures capable of maintaining high strength and resistance to oxidation at high temperatures has created wide interest in René 41 and other superalloys. René 41 is a vacuum-melted, nickel-base alloy whose nominal composition includes 19 Cr, 11 Co, 10 Mo, 3.1 Ti, 1.5 Al, 0.1 C and small amounts of silicon, manganese, iron, sulfur and boron. Its characteristic high strength at elevated temperatures is developed by the precipitation of a gamma-prime phase, $Ni_3(Al, Ti)$, during heat treatment.

René 41 can be seam and spot welded without major difficulty. However, consistent reproduction of high-quality structural welds from pre-established schedules has been difficult. Solutions to this problem led to welding equipment and techniques unlike those required for joining other materials. These are required because of certain fundamental properties of the alloy.

René 41 has low thermal conductivity and high electrical resistivity compared to stainless steel, aluminum alloys and most nickel-base

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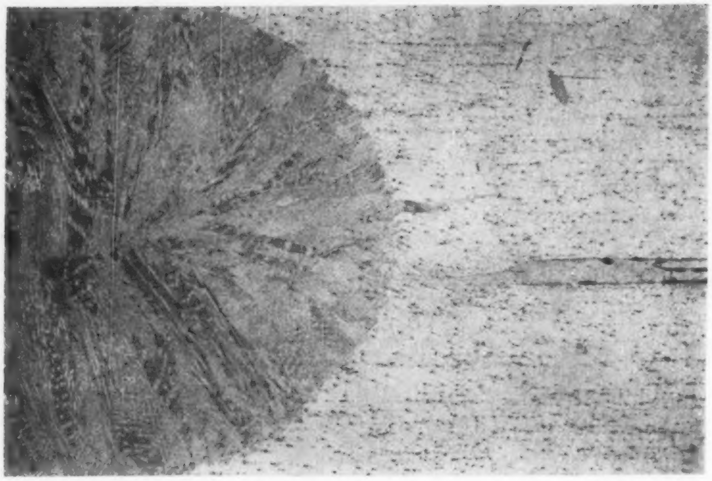


Fig. 1 – Macrograph Shows That Hot Molten Weld Metal Was Squeezed Out of the Nugget. This defect occurs if welding current is too high. Etchant: 92% HCl, 5% H_2SO_4, 3% HNO_3; 50 ×

alloys. Under these conditions, high-amplitude welding current causes an extremely rapid heat buildup at the weld joint interface. The metal at the interface may pass through its narrow melting range (the liquidus and solidus temperatures are only 50 to 100° F. apart) so rapidly that the spot weld machine pressure system has insufficient time to maintain the required electrode force. The delayed force application expels molten metal into the interface surrounding the nugget – a condition which is not acceptable. This condition is illustrated in Fig. 1.

On the other hand, current applied at an amplitude low enough to prevent this expulsion and with a duration sufficient to permit proper nugget growth along the interface results in a thermal equilibrium condition which significantly limits nugget penetration. In addition to marginal nugget penetration, "macrosegregation", another undesirable metallurgical phenomenon, can result from insufficient current amplitude. This condition can be characterized by distinct bands or areas of heterogeneous material within the cast structure of the weld nugget. An illustration of macrosegregation is shown in Fig. 2.

To establish welding schedules insuring nugget penetration well within the acceptable range, we had to devise a method for using increased weld current amplitude without molten metal expulsion. The problem was solved by preceding a high-amplitude, short-duration weld current with a lower-amplitude (normally 50% of the weld current) "preheat" current. The preheat amplitude is just sufficient to create a surface bond at the joint interface. This bond permits more rapid heat buildup due to high-amplitude welding current, and consequently greater penetration without expulsion of molten weld metal into the joint interface. It is important that alternate heating and cooling of the growing weld nugget be minimized.

Properties Affect Weldability

Phases other than the gamma prime, including the carbides M_6C and $M_{23}C_6$, have an important influence on the physical properties of resistance welded René 41. (See "How to

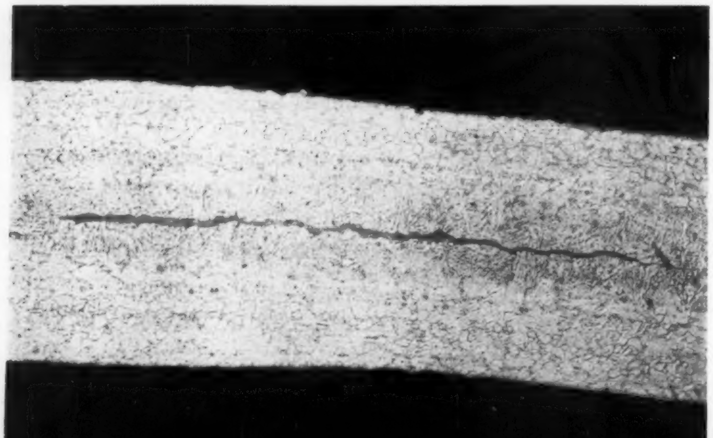


Fig. 2 – Insufficient Heat During Welding Not Only Causes Insufficient Nugget Growth in René 41, But Also Leads to Macrosegregation as Shown Here. Etchant: 92% HCl, 5% H_2SO_4, 3% HNO_3; 50 ×

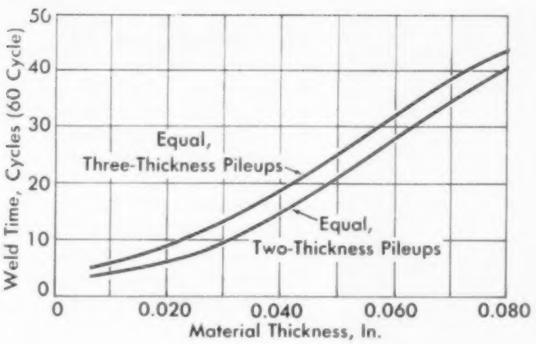


Fig. 3 – Recommended Duration of Uninterrupted Single-Polarity Current (Weld Time) for René 41 Spot Welds. Preheat time and forging time are equal, in duration, to weld time

Fabricate René 41", by Louis A. Weisenberg and Robert J. Morris, *Metal Progress*, November 1960, p. 70.) The mill form of René 41 exhibits a fine grain structure with M_6C carbides randomly dispersed. Above about 2000° F. this carbide goes into solution. On subsequent cooling through the 1400 to 1550° F. range, a far more undesirable carbide, $M_{23}C_6$, precipitates in a continuous weakening network along boundaries of enlarged grains. The accumulation of $M_{23}C_6$ increases in proportion to time and frequency at 1400 to 1550° F.

For this reason, repeated heating and cooling through the critical temperature range, characteristic of multiple impulse spot welding, results in a considerable accumulation of the $M_{23}C_6$ carbide. It is possible to alleviate this condition by solution treating at 1950° F. after spot welding and prior to aging. However, this is not always practical for large assemblies because of distortion and furnace size limitations. Consequently, in order to minimize time and frequency in the critical $M_{23}C_6$ carbide precipitation range, we found it desirable to use uninterrupted single-polarity current for welding ("weld time") and for preheat. One polarity reversal between preheat and weld time is unavoidable due to equipment limitations. Typical weld time requirements for equal two and three thickness pileups are given in Fig. 3, as a function of material thickness. The equipment requires a preheat of equal duration.

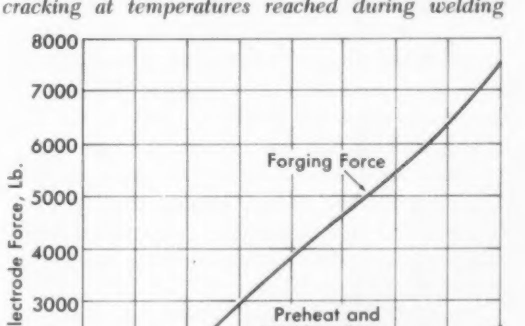
Controlling the Forging Force

In the mill-annealed condition, René 41 has a tendency to crack at elevated temperatures (hot cracking). To offset this tendency and to increase grain refinement, a postweld compression (forging force) is required. Best results have been obtained using a forging force two to three times the force required for preheat and welding. This relationship is shown as a function of material thickness in Fig. 4. Because René 41 retains much of its high mechanical strength at elevated temperatures, this welding and forging electrode force requirement is nearly double that needed for resistance welding comparable thicknesses of aluminum.

The current amplitude for postweld forging is that required to raise the weld nugget up to recommended forging temperature (1800° F.). Since there is no way to measure this temperature during welding, the forging current amplitude must be established by trial and error. Nuggets made using progressively higher forging current amplitude settings are sectioned and examined. Insufficient current normally fails to remove cracks; excessive current results in remelting and extrusion of molten metal into the interface surrounding the weld nugget.

This current amplitude depends directly on the amount the nugget is permitted to cool after welding time, and, therefore, on the time delay at polarity reversal. Acceptable spot welds have been made using time delays (quench time) of from three to 20 cycles of time; however, we found a delay of three to six cycles to be optimum. The duration of the Postweld current is limited by the equipment

Fig. 4 – Recommended Electrode Force for Preheat, Welding and Postweld Forging René 41 Spot Welds. Proper relation between the forces will minimize cracking at temperatures reached during welding



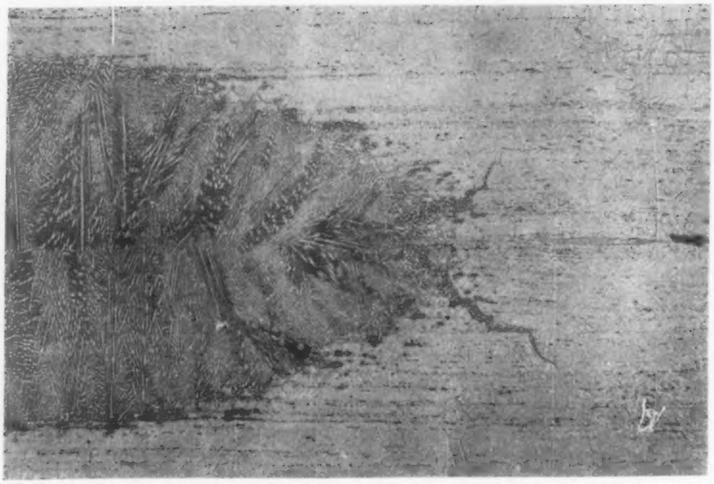


Fig. 5 – Macrograph Shows Effect of Incipient Melting of a Eutectic Phase During Spot Welding of René 41. In this instance, the low-melting liquid was extruded into cracks where it then solidified. If unfilled cracks are not in evidence, the condition is not considered a reason for rejection. The eutectic may melt in service, however

to exactly that required for weld time.

In order to obtain the precise relationships between preheat, welding, and forging current application, accurate timing is essential. Systems using resistance-capacitance (RC) type actuating circuits are not the most desirable. They exhibit large mechanical timing delays which are subject to considerable variation resulting from heatup of equipment. On the other hand, equipment having digital control of timing circuits which are not subject to mechanical variations has been used successfully.

However, inertia and frictional instabilities in the pneumatic activating system and pressure head still result in minor delays of one to two cycles of time. Consequently, forging force must be initiated one to two cycles before its full amplitude is required with respect to postweld current application. This is accomplished by a preset timing circuit which counts out the "forge delay" from the initiation of weld time.

Another occasional characteristic of René 41 spot welds is shown in Fig. 5. This is the incipient melting and resolidification in the heat-affected zone (away from the cast nugget structure) of a low-melting-point eutectic phase. It is normally formed within, or extruded into, planes of weakness near the interface periphery of the weld.

Provided that incipient melting is not evidenced by cracking, it is presently considered acceptable. Neither its distinct cause or prevention has been firmly established. The greatest concern is the possibility that this eutectic may remelt at elevated temperatures, subsequently weakening the spot weld.

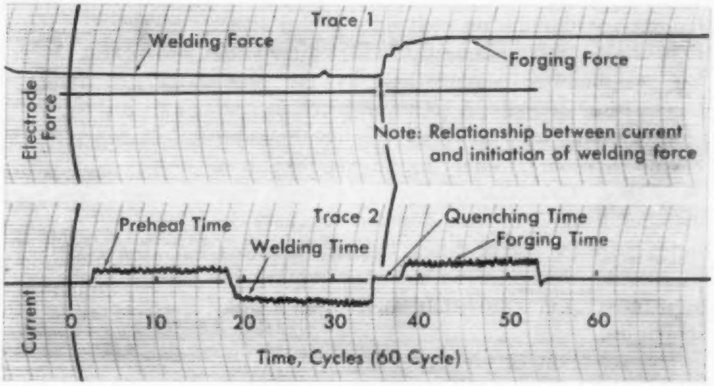
Setting Up a Welding Schedule

An awareness of these physical relationships between welding current, electrode force and time is not in itself sufficient for establishing and precisely reproducing spot weld schedules for René 41. In production, settings must be reproduced on various slightly dissimilar machines, as well as on the same machine after periodic maintenance or modifications. For this reason, oscillographic traces showing timing of current and electrode force are essential. A typical recording for a 0.040 to 0.040-in. René 41 spot weld is shown in Fig. 6. Trace 1 indicates welding and forging force versus cycles of time. Trace 2 indicates uninterrupted single-polarity current for preheat, welding and postweld forging versus cycles of time. Note the relationship between current and the initiation of forging (welding) force.

In setting up a weld schedule, conformance of spot welds with process specification requirements is determined from micro and macroexamination of weld cross sections and from evaluation of bend test and shear strength values. Cut and polished macro specimens are electrolytically etched in 10% chromic acid solution. These specimens are evaluated for nugget penetration and diameter as well as evidence of cracking, macrosegregation, or expulsion of molten weld metal into the interface surrounding the nugget. Evidence of incipient melting is established only from micro-examination.

Process limitations and design requirements are major factors in establishing minimum spot weld strengths. Recent experiments indicate

Fig. 6 – The Oscillograph Traces Show Timing of Electrode Force (Trace 1) and Current (Trace 2) During Spot Welding of Two 0.040-In. Sheets of René 41. Because of a one to two-cycle delay in its actuating system, the forging force must be started before the free amplitude is required with respect to postweld current



that a maximum strength level is also desirable as a means to prevent overheating and subsequent excessive grain growth. Also, the excess pressure required can result in considerable indentation (on aerodynamic surfaces) and sheet separation. This could also be a factor affecting equipment and electrode wear.

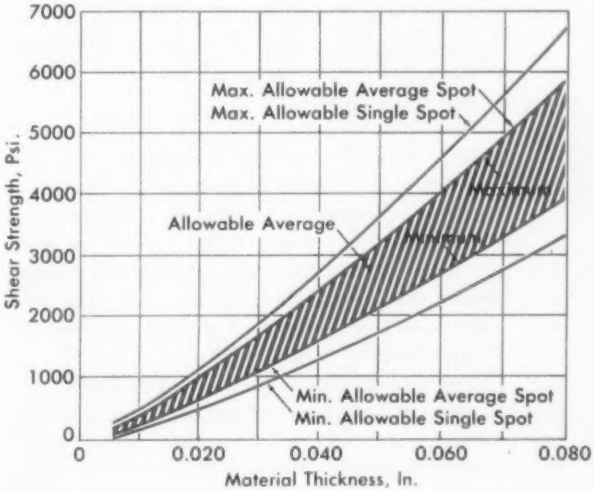
Figure 7 indicates limits established by Boeing for allowable single spot weld shear strengths and allowable average spot weld shear strengths. These limits are used as a guide in developing René 41 spot weld schedules. To be statistically confident that no spot weld strength falls outside the established single spot weld limits, the "average allowable" band is considerably narrower. Boeing specifications allow a ±10% variation during production from the average shear strength established when the schedule was determined – provided the new average value does not fall outside this narrow band. Hence, it is desirable to establish a weld schedule that produces an average shear strength as near the center of this inner band as possible. This allows full advantage to be taken of process allowables without jeopardizing weld quality and reliability.

Shims Solve Problem

Control of nugget penetration is a major problem in spot welding sheets of unequal thicknesses. The weld nugget tends to nucleate from the geometric center of the stack rather than from the joint interface, because comparatively long-duration welding time is required. Consequently, a metallic shim is placed in contact with the thinner member to add resistance to the flow of current and cause nucleation of the nugget closer to the thin sheet. Thickness of the shim is dictated by the thickness ratio of the members being welded; the greater the thickness ratio, the thicker the shim must be. Nickel-base alloy and 300 series stainless steel shims have been used successfully. Shims are removed after welding. To date, this technique enabled us to weld René 41 sheets with thickness ratios up to and including 4 to 1.

Stacks of three and four sheets of various thicknesses may also be welded with the aid of shims. Combinations having a single heavy member flanked by two thinner members often

Fig. 7 – Limitations on Minimum and Maximum Shear Strengths for René 41 Spot Welds Are Used to Determine Proper Settings on Production Machines and for Quality Control. Variations of ±10% from an average shear strength established for a particular machine are permitted during production if the strength that is obtained does not fall outside the average allowable band



require use of shims on both sides of the stack. Four-sheet stacks are usually welded after joining two-member combinations by the techniques discussed above. The presence of previously made spot welds in this combination has no detrimental effect on nugget formation or quality. Combinations having a single thin member flanked by two heavier members do not require the use of shims. Minor variations in material thickness (within 10%) require no adjustments in pre-established spot weld schedules.

The selection of electrode materials is important. Electrodes of RWMA Grade A, Class 3 type, which exhibit a hardness of Rockwell B-100 and electrical conductivity of 48% (I.A.C.S.), performed well. In continuous production, these electrodes can produce over 1000 consecutive spot welds without significant electrode tip wear or changes in weld nugget geometry or properties. Full-faced ⅝-in. diameter electrodes having tip radii of 4 to 8 in. should be used wherever possible. If the electrode face must be reduced for specific applications, useful electrode life will be correspondingly reduced.

Avoid Surface Contamination

The absence of foreign materials and markings from surfaces to be joined is desirable for resistance welding nickel-base alloys. This is a primary consideration for welding René 41 alloy.

Nickel-base alloys become brittle when exposed at elevated temperatures to sulfur, lead, zinc, and some other low-melting, eutectic-forming metals and alloys. Sulfur is contained in many machining lubricants, marking crayon compounds and paints. Many tooling materials contain the low-melting metals either singly or in combination.

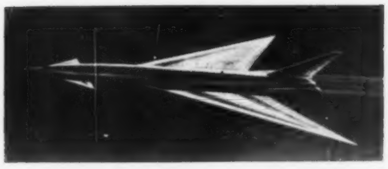
Also, carbon from soils, ink markings and paints can under certain conditions form adverse $M_{23}C_6$ carbides at grain boundaries in a continuous weakening network. Entrapment of high-melting surface oxides within the nugget also weakens the weld. Nearly all surface oxides and films resist the flow of electrical current to some extent. This is detrimental to reproducibility in spot welding.

Precautions should be taken that metal surfaces to be joined are not contaminated, thereby offering no greater resistance than 100 microhms per circular-mil-ft. under 1000 lb. of axial load; surface finish should not exceed 63 micro-in.

These requirements can be met if the sheet is thoroughly cleaned. To accomplish this we subject the parts to a five-step cleaning in the following sequence: *(a)* degrease in trichloroethylene at 190° F. to remove heavy grease and oils; *(b)* immerse in alkaline bath of phosphosilicate (5 to 7 oz. per gal. of water) at 180° F. to remove lighter oils, markings, and fingerprints; *(c)* spray with high-pressure water, followed by warm water rinse; *(d)* pickle in a 20% nitric-4% hydrofluoric acid bath at 120° F. for not over 2 min. to remove surface oxidation and metal deposits remaining from previous fabrication operations; and *(e)* spray with high-pressure water to remove smut remaining after the pickling operation. Small oxidized areas that remain or subsequently accumulate may be removed by abrasive cleaning. In addition, all parts should be cleaned immediately prior to welding by wiping with a solvent such as methyl-ethyl-ketone. All assemblies and parts should be protectively wrapped between operations and handled only with the aid of clean cotton gloves.

Seven Steps to Successful Seam and Spot Welding of Rene 41

- Employ uninterrupted, single-polarity, high-amplitude, short-duration welding current preceded by single-polarity, lower-amplitude preheat current to insure ample nugget penetration.
- Provide uninterrupted single-polarity current with higher electrode force (two or three times welding force) for postweld forging of the spot weld nugget.
- Use oscillographic traces for precise timing of current and electrode force when determining welding schedule and setting it up on production equipment.
- Check spot weld shear strengths periodically to insure consistent reproduction of high-quality welds.
- Clean thoroughly all parts to be welded so that they are completely free of contaminating soils and oxide films.
- After initial qualification, check all spot welding machines at intervals not to exceed 30 days.
- Offer all machine operators and quality control personnel informative training.



Progress in High Temperature Metals

Two Superalloys for Jet Engines

Udimet 700, a Wrought Alloy

*By I. S. SERVI and W. J. BOESCH**

This alloy, commonly used for turbine buckets, is also employed for wheels and shafts of jet engines. Bar and billet stock is available commercially, and sheet and wrought shapes are being tested for new applications. (A-general, T24b, 17-57; Ni-b, SGA-h)

UDIMET 700, INTRODUCED IN 1957, is a wrought alloy for 1800° F. service. Initial production consisted of small-sized stock processed from 9-lb. ingots. Today, 1 to 4-in. stock for regular industrial use is being rolled from ingots weighing up to 2000 lb. The demand for still larger stock is being filled. Several 8 to 14-in. diameter billets have been successfully produced, some from ingots weighing over 4500 lb. It is expected that the alloy will also be produced in sheet and other wrought forms.

*Vice-President and Manager of Technical Services, respectively, Special Metals, Inc., New Hartford, N.Y. "Udimet" is a registered trade name.

IN-100, a Cast Alloy

*By S. F. STERNASTY and E. W. ROSS**

The reported high stress-rupture strength of this alloy has stimulated a detailed evaluation of its producibility and properties. Results indicate that it can be used for turbine blades and other high-temperature applications for advanced jet engines. (A-general, T24b, 17-57; Ni-b, SGA-h)

THE FIRST TECHNICAL REPORT on IN-100, one of the newest of the superalloys, appeared but a short time ago in *Metal Progress* (April 1961, p. 97). Since the preliminary data given in that article indicated the stress-rupture capability of the alloy to be 50 to 75° F. higher than that of any superalloy then available, we became interested in it for turbine blades.

In evaluating an alloy for a specific application, the engineer first must know the operating conditions that the component will experience. Next, he must establish all the properties that will be needed by the design and determine whether parts with uniform properties can be

*Engineer and Supervisor, respectively, Structural Materials Unit, Large Jet Engine Dept., General Electric Co., Cincinnati, Ohio. A development of the International Nickel Co., IN-100 is a nickel-base alloy containing 10 Cr, 15 Co, 3 Mo, 1 V, 5.5 Al, 5 Ti, 0.18 C, 0.015 B, and 0.05 Zr.

Udimet 700

The metallurgy of this alloy is rather interesting. It is a typical nickel-chromium-cobalt alloy in which aluminum and titanium are the hardening agents. In the as-rolled condition, the structure contains a large amount of gamma prime [Ni_3 (Al, Ti)], some MC and M_3B_2, and a small amount of $M_{23}C_6$. The M_3B_2 is mainly a molybdenum-chromium boride, and the MC is titanium carbide, with some dissolved molybdenum and chromium. Other elements may also be present in the latter compound. There are large amounts of gamma prime because the alloy is hot rolled in the two-phase field (gamma plus gamma prime) and gamma prime is progressively rejected from the matrix.

A 4-hr. heat treatment at 2150° F. ±25° is essential to assure complete solutioning of the gamma prime, otherwise the high-temperature properties will be drastically impaired. Conversely, when the alloy is to be hot formed in some manner, solutioning should be avoided by ascertaining that the metal is not heated above 2025° F. ±25°. The molybdenum-rich M_3B_2-type phase decomposes and melts above 2200° F. ±25°. The result is a eutectic composed of a M_3B_2 type compound (rich in chromium-nickel-cobalt) and a gamma matrix (melting point: 2220° F. ±10°).

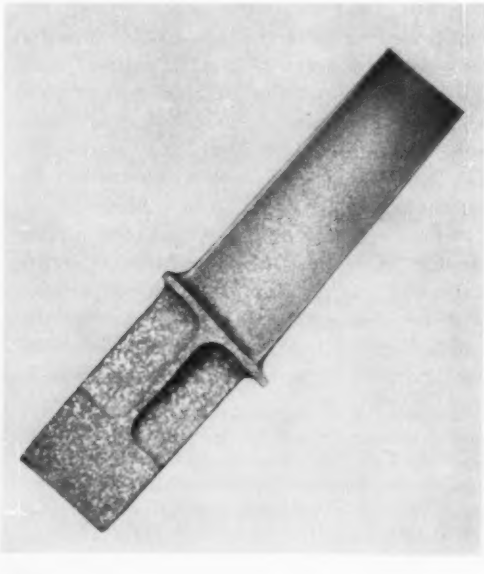
How to Age the Alloy

When a properly solutioned Udimet 700 part is treated at 1975° F., gamma prime precipitates in coarse, discrete particles to produce, in effect, mild overaging. However, subsequent aging at lower temperatures and air cooling cause a fine gamma prime of slightly different composition to precipitate within the gamma matrix. This treatment hardens the alloy completely. Thus, full heat treatment consists of thorough solutioning, high-temperature aging, and one or two aging treatments at lower temperatures. During the latter heating, $M_{23}C_6$ also precipitates but this phase does not impair engineering ductility.

For use at 1800° F. the recommended heat treatment is: Heat at 2150° F. for 4 hr., air cool, heat at 1975° F. for 4 hr., air cool, heat at 1550 F. for 24 hr., air cool. heat at 1400° F. for

IN-100

Fig. 1 – Cast Turbine Blade Showing Variations in Grain Size Which Occur During Solidification and Cooling. These variations are within the limits set up by the manufacturer. 1 ×



produced of the alloy in question. Of particular importance is the grain size. Investment casting techniques used in producing turbine blades can result in large variations in grain size from blade to blade and even within a blade. Since this variable is known to have a significant effect on many of the properties, we established a range of grain sizes which would result in the best compromise of mechanical properties in the component.

To date three producers have vacuum cast two types of blades from IN-100 alloy according to our stringent specifications. As Fig. 1 shows, the grain sizes vary; however, they are within the required range. Though tears and microshrinkage were experienced in some of the initial castings, both of these problems have been rectified by modifying the casting techniques. Thus, manufacturers currently produce blades to guaranteed quality requirements and mechanical properties, including the stress-rupture specification which requires a 23-hr. minimum life on test bars machined from cast blades and stressed at 29,000 psi. at 1800° F.

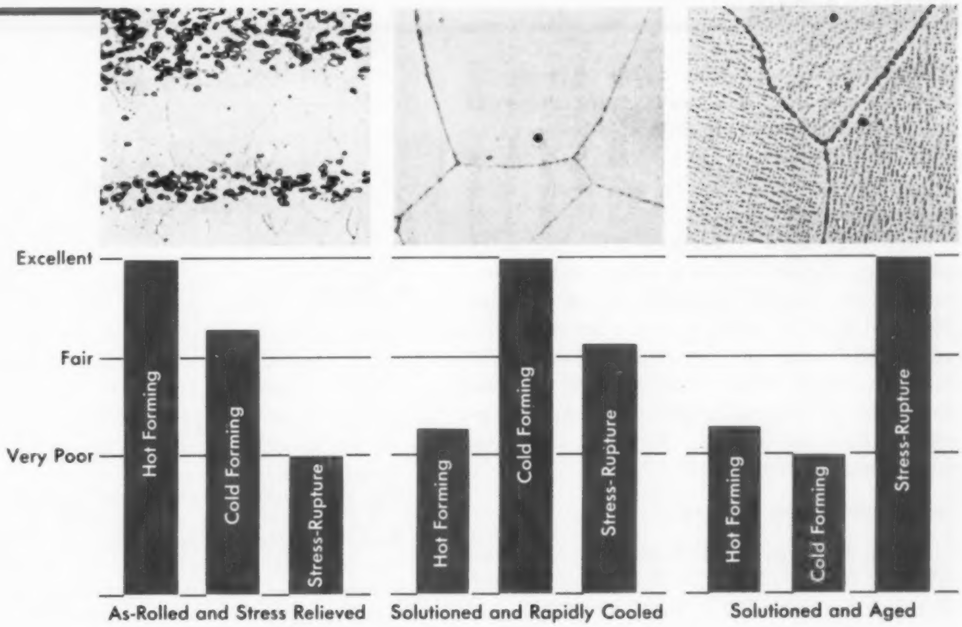


Fig. 1 – Microstructures of Udimet 700 As-Rolled and Stress Relieved (Left) Solution Treated (2150° F.) and Cooled Rapidly (Center), and Solution Treated (2150° F.) and Aged (1975-1550-1400° F.). The major constituent is gamma prime in a gamma matrix. Etchant; Kalling's reagent; 1000 ×

Once the casting technique and reproducibility of the blades have been established, the property levels obtained in the castings must be evaluated. For this we machined specimens from the blades and tested them for stress-rupture and tensile data. The results are shown in Fig. 2 and 3.

The designer must also know how an alloy will act when it is subjected to combined stresses (a mean stress plus a superimposed alternating stress). Thus we also use a "stress-range"* diagram in Fig. 4; it shows the alloy behavior under varying stress combinations.

Another important design consideration is the "thermal fatigue crack" a low-cycle, high-stress fatigue failure which is induced by the severe thermal gradient experienced by the blade during engine starting. In a test† appa-

In recent years, aircraft gas turbines and new superalloys have made parallel progress. This is not surprising – each new development in either field is a stimulating challenge to the other. Designs for more powerful engines call for stronger alloys and vice versa.

However, before any new alloy can be applied, the designer must know what it can do. These two articles, in reporting comprehensive test results on Udimet 700 and IN-100, two important new superalloys, should therefore be of interest to all engineers concerned with improving the performance of today's jet engines.

*A "stress-range" diagram, also called a "modified Goodman" diagram, is normally made up for a given temperature; the curve represents a certain number of hours of life. The X axis is mean stress (rupture life), the Y axis is alternating stress (fatigue), and the area between represents a combination of mean and alternating stresses. This type of information is essential in turbine blade design, since the component is subjected to a combination of mean stresses (the centrifugal loads) and alternating stresses (the gas loads).

†Although the actual details of this test are proprietary, it might be generally stated that the airfoil of the blade is rapidly heated to testing temperature, held until the temperature is uniform, and quickly air cooled. The blade is cycled in this manner until it fails.

Udimet 700

16 hr., and air cool. This treatment yields the best compromise of stress-rupture properties and room-temperature ductility. Moreover, the alloy is fully stabilized, so that little or no changes in properties are to be expected after exposure at 1800° F.

Most processing operations with this alloy can be performed within a range of temperatures. For example, it can be forged between 1800 and 2050° F., stress relieved between 1850 and 2000° F., and aged between 1400 and 1975° F. The actual temperatures selected for heat treatment will depend largely on the final properties which are desired. Figure 1 illustrates typical microstructures.

Compositions and Properties

Nominally, this nickel-base alloy contains 3.75 to 4.75 Al, 2.75 to 3.75 Ti, 4.50 to 5.50 Mo, 13 to 17 Cr, 14 to 20 Co, 0.001 to 0.050 B and given levels for C (0.15 max.) and Fe (4.00 max.). To assure reproducibility of properties, the composition is controlled within much narrower limits by vacuum induction melting, either applied as such or followed by consumable arc remelting.

A broad picture of stress rupture properties

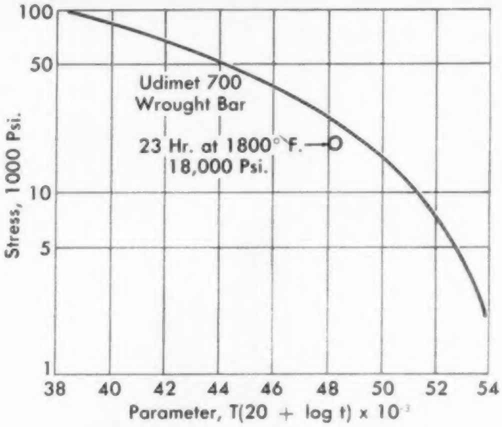


Fig. 2 – Stress-Rupture Properties of Udimet 700 (Wrought Bar) as Indicated by Larson-Miller Plot Derived From Tests up to 2100° F. The material has received the recommended treatment for the best compromise of stress-rupture properties and room-temperature ductility

IN-100

ratus that simulates such stresses, IN-100 alloy blades were tested along with cast Udimet 500 and cast Udimet 700. The data indicated that its resistance to thermal fatigue cracking was twice that of Udimet 700 and 3.5 times that of Udimet 500. The thermal coefficient of expan-

Fig. 2 – Yield and Ultimate Tensile Strength of IN-100 Alloy as Obtained From Tests on Cast Turbine Blades

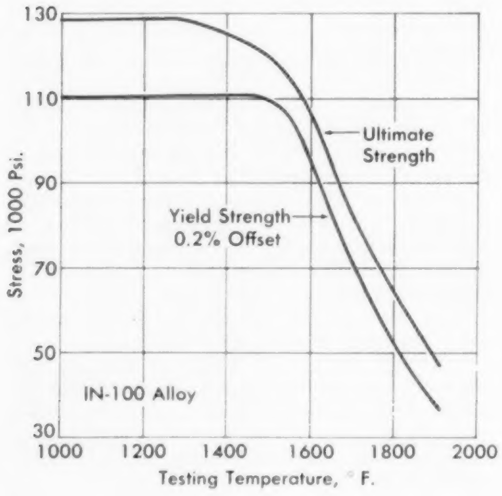
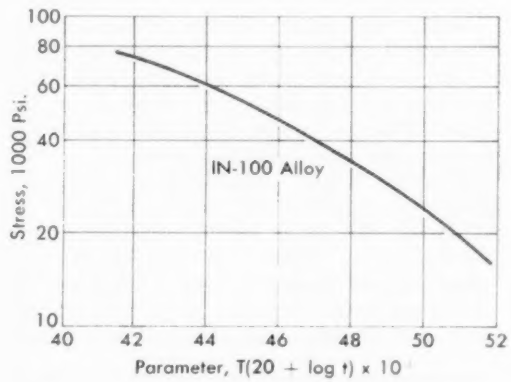


Fig. 3 – Larson-Miller Curve Indicating Stress-Rupture Properties of IN-100 Alloy. The 100-hr. rupture life data for this curve were obtained from specimens machined from cast turbine blades. "T" is in Rankine degrees, "t" in hr.



is given by the Larson-Miller curve (Fig. 2). Though tensile tests at conventional speeds indicate useful engineering strength up to about 1950° F., the situation changes when fast strain rates are used. As Fig. 3 shows, a reasonable strength is maintained up to 2100° F. under such conditions.

A number of variables, including the temperature and mode of hot working, affect the tensile properties of this alloy. Among them is the degree of residual "hot-cold work". Because of this, the properties reported in Fig. 3 represent the lower end of typical performance. Without a thorough solution treatment (2150° F.), much higher tensile properties at room and moderate temperatures are obtained, but the stress-rupture preformance at high temperature

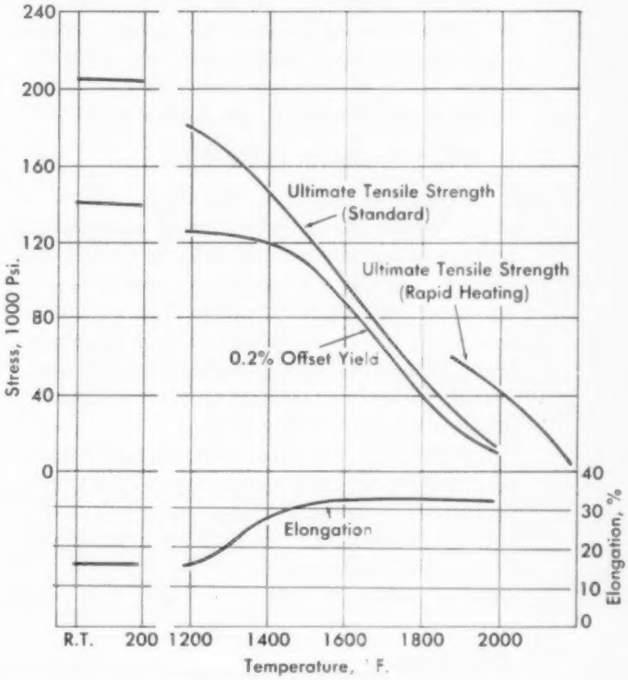


Fig. 3 – With Rapid Testing Rates, the Tensile Strength at a Given Temperature Is Higher Than That Indicated by Hot Tensile Testing at Conventional Rates. For those tests, the bars (gage diameter, 0.25 in.) were heated to temperature in 30 sec. and pulled to fracture at 0.1 in. per in. per sec.

sion and the dynamic modulus of elasticity were also determined and are presented in Fig. 5.

Phases Are Important

Though the phases present in an alloy seem to be only of academic interest, they are important from a practical standpoint, as well. Often, an understanding of the phases present and their relationships to the properties obtained can aid in improving the alloy through heat treatment or chemistry variations. In this investigation, electron microscopy, x-ray diffraction and fluorescence analysis techniques were used to study the phases and their morphology in samples, both as-cast and after exposure at engine operating temperatures.

The alloy is strengthened by precipitation

Fig. 4 – "Stress-Range" Diagram for IN-100 Alloy. These data represent combined stresses. To obtain them, alternating stresses were imposed on specimens already under a given mean stress (at 1500°F.)

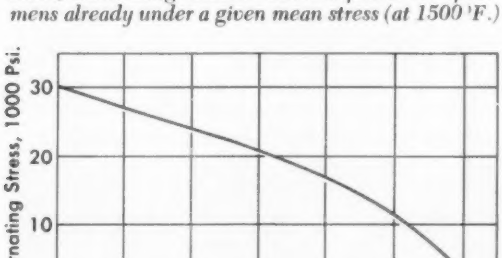
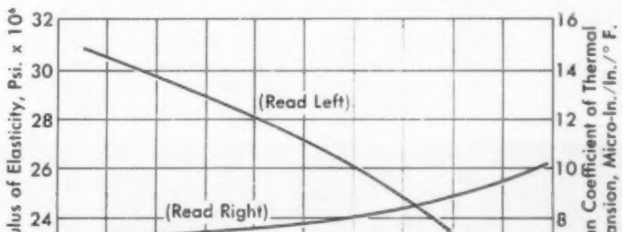


Fig. 5 – Modulus of Elasticity and Coefficient of Thermal Expansion at Various Temperatures



Udimet 700

is severely impaired. So far, sheet stock has not been evaluated completely, but tensile properties at room temperature and 1300° F. appear to be in line with those of bar stock, except that elongations are somewhat lower.

Oxidation Resistance Is Good

As would be expected, the alloy oxidizes in a manner similar to other nickel-base alloys. It can be used unprotected in air at least up to 1800° F. At and above 2000° F., scaling is not excessive, but critical elements such as aluminum and titanium are removed from a surface layer. Therefore, protective coatings are suggested, particularly for thin sections which are designed to last for long periods.

Oxidation is critically affected by surface preparation. As Fig. 4 demonstrates, cold working results in intergranular attack – eventually leading to spalling. Furthermore, the figure shows that electropolishing aids oxidation resistance. After the test, only a very thin subscale was evident, intergranular attack being virtually absent.

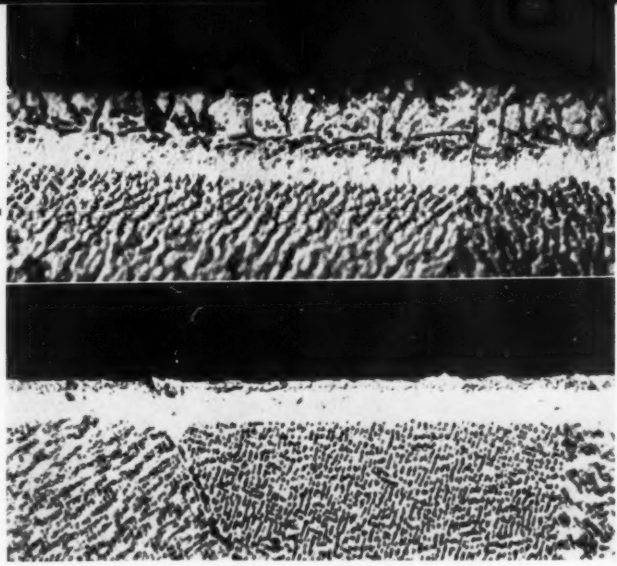


Fig. 4 – How Surface Condition Affects Resistance to Oxidation. After grinding (top) and electropolishing (bottom), the specimens were exposed to still air at 1800° F. for 100 hr. Though the ground specimen corroded to 0.0005 in., the other formed only a thin scale and intergranular attack was virtually absent. Etchant: Marble's reagent; 1000 ×

IN-100

hardening. Gamma prime, Ni_3 (Al, Ti), precipitates from the matrix as the component cools from the solidification temperature. The relatively high amounts of aluminum and titanium form another gamma prime (the white "islands" in Fig. 6 and 7) that emerges from the liquidus rather than precipitating from solid solution. The alloy contains a large amount of MC (M being predominantly titanium) in both the as-cast condition and after various exposures to elevated temperatures (although it does decrease somewhat with increasing exposure). A chromium-rich carbide, $M_{23}C_6$, is not present in the as-cast condition, but is formed during exposure as the MC breaks down.

Different casting techniques produce varying MC morphologies which apparently affect the fatigue strength. Structures with elongated carbides (Fig. 7) have been shown to have the same life in combined stress fatigue as structures with equiaxed carbides (Fig. 6) at stresses that are as much as 30% higher.

Because vanadium is a carbide former, it usually exists as a vanadium carbide. In this alloy, however, vanadium seems to be primarily a solid-solution strengthener, or a replacement for titanium in the gamma prime.

Fig. 6 – General Microstructure of IN-100 Alloy. The small, clearly defined particles are MC, and the white "islands" are presumably gamma prime that emerged from the melt on solidification. Etchant: Kalling's reagent; 300 ×

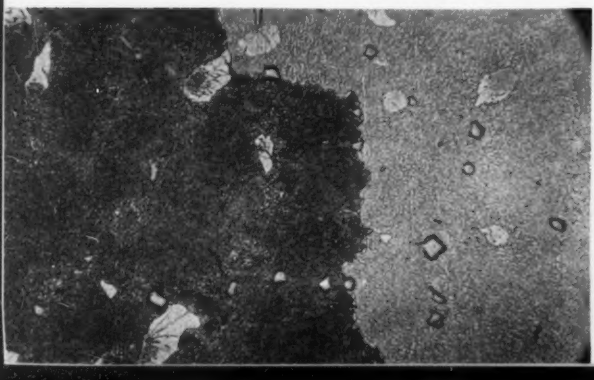
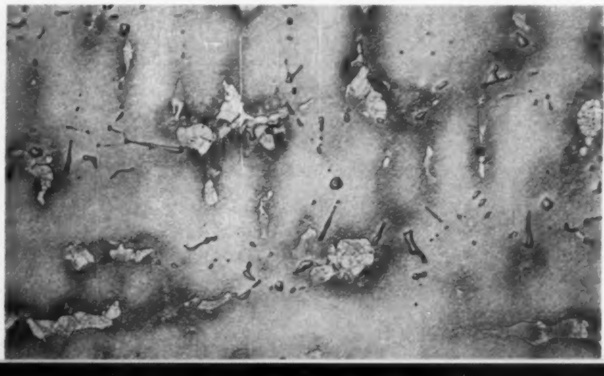


Fig. 7 – In This Microstructure, the MC Particles Are Elongated Rather Than Round As In Fig. 6. This structure had much better fatigue strength under combined stresses than did the other, Etchant: Kalling's reagent; 250 ×



Vacuum Melting Improves Properties of H11 Steel

By P. E. RUFF
*and R. W. STEUR**

Consumable-electrode, vacuum-melted H11 steel is probably cleaner than its air-melted counterpart, but the size, shape and distribution of inclusions may have a more important effect on properties than do quantitative differences. This may explain why vacuum-melted steel has superior transverse ductility, more uniform properties, higher notched tensile strength and greater fatigue strength than air-melted material. (D8m, Q-general; TS, SGB-s)

THE APPLICATION of H11†, a 5% Cr hot work tool steel, for aircraft structures was described in *Metal Progress* in March 1959 (p. 103) and April 1959 (p. 97.). The mechanical properties given in the first article were obtained from H11 steel, air melted in basic electric furnaces. As pointed out in that article, low transverse ductility in large bars was a major problem with air-melted material. As soon as the consumable-electrode, vacuum-melting process became available, its effect on the quality of H11 was investigated. In this process, an air-melted electrode is arc remelted in a vacuum at a controlled rate. The ingot solidifies in a water-cooled copper mold.

Air and Vacuum-Melted H11 Compared

A comparison of mechanical properties (in the short transverse direction) of large air-melted and consumable-electrode, vacuum-melted (CEVM) bars is presented in Table I. The data that are listed represent typical results from tests on bars of various sizes and from a number of heats. They show that the transverse reduction of area of CEVM material is considerably better than that of air-melted H11. In addition, tensile specimens taken from the center of CEVM bars exhibited good ductility; and vacuum-melted material also displayed much better uniformity throughout the cross section. As a result of these improvements, our material specification for CEVM H11 now establishes an 8% minimum and 10% minimum average for reduction of area at 280,000 to 300,000 psi. for both center and mid-radius short transverse locations. For air-melted material, suppliers guaranteed a minimum reduction of area of 6% at midradius; no guarantee is made for the center position within the

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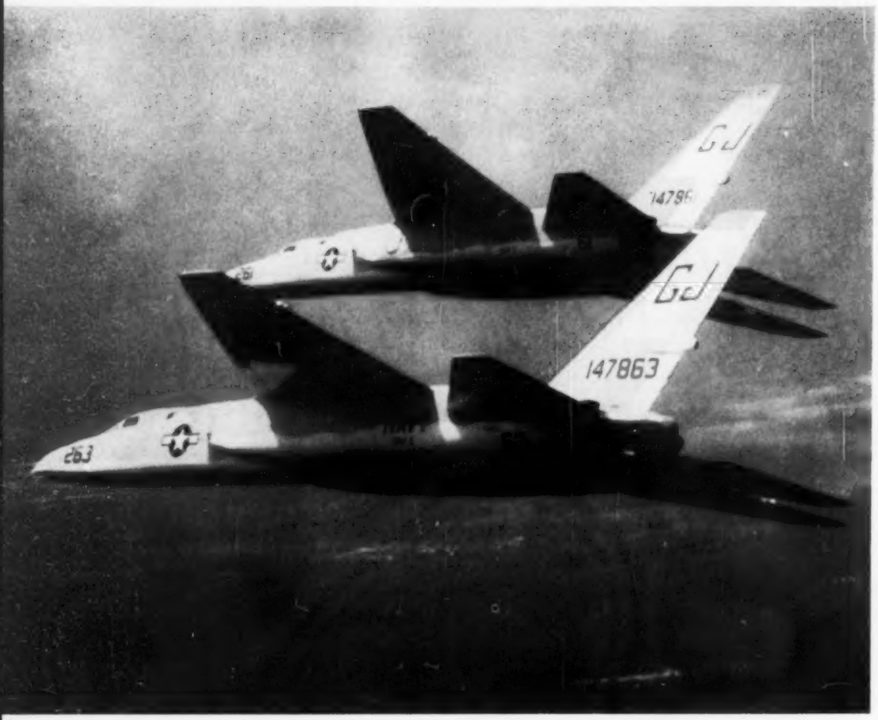
†H11 steel has the following nominal composition: 0.40 C, 0.30 Mn, 0.90 Si, 5.00 Cr, 1.30 Mo and 0.50 V.



Important Structural Members in A3J-1, Navy's Newest and Largest Carrier-Based Attack Aircraft, Are Made of Consumable-Electrode, Vacuum-Melted H11 Steel

same strength range. Suppliers have found the producibility of CEVM H11 steel far superior to air-melted material.

Forgings Improved

Figure 1 is a photograph of the aft fuselage frame for the A3J-1, a heavy attack aircraft being built for the Navy by North American Aviation in Columbus, Ohio. This assembly is composed of parts machined from H11 die forgings. A comparison of the mechanical properties for some of these forgings made from CEVM material and air-melted H11 is presented in Tables II and III. (Figures 2 and 3 show the positions from which the test bars were cut.) The data clearly indicate improved

Fig. 1 – Aft Fuselage Frame of A3J-1, Measuring 186-In.-Wide, Is Made Up of H11 Forgings. How vacuum melting affects the properties of the horizontal and vertical spindles is shown in Tables II and III

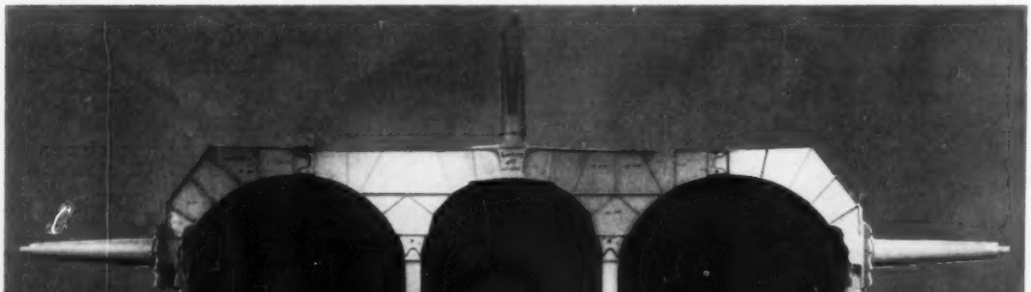


Table I – Transverse Mechanical Properties of Air-Melted and Consumable-Electrode, Vacuum-Melted H11 Steel (10 × 12-In. Bar)

Specimen Location	Ingot Position	Air-Melted			Consumable-Electrode, Vacuum-Melted		
		Yield Strength (0.2% Offset)	Ultimate Tensile Strength	Reduction in Area	Yield Strength (0.2% Offset)	Ultimate Tensile Strength	Reduction in Area
Midradius	Bottom	247,000 psi.	293,000 psi.	13.1%	243,000 psi.	287,000 psi.	16.1%
Midradius	Bottom	246,000	293,000	15.8	239,000	287,000	12.8
Center	Bottom	251,000	299,000	5.2	238,000	283,000	15.3
Center	Bottom	250,000	290,000	4.0	228,000	276,000	20.9
Midradius	Top	248,000	293,000	5.4	238,000	282,000	13.3
Midradius	Top	250,000	295,000	6.2	231,000	284,000	16.4
Center	Top	249,000	293,000	6.6	237,000	282,000	14.8
Center	Top	253,000	298,000	7.1	237,000	282,000	12.7

Table II – Mechanical Properties of Air-Melted and CEVM H11 Steel Vertical Spindle Die Forgings

Bar Number*	Test Direction†	Yield Strength, Psi.	Ultimate Tensile Strength, Psi.	Elongation‡, %	Reduction in Area, %
		Air-Melted			
1	ST	235,000	284,000	4.9	8.2
2	ST	233,000	284,000	3.7	8.1
3	ST	235,000	281,000	2.5	6.6
4	ST	236,000	283,000	2.3	7.6
5	L	240,000	288,000	9.0	34.4
		Consumable-Electrode, Vacuum-Melted			
1	ST	239,000	291,000	11.3	36.7
2	ST	243,000	296,000	9.0	29.8
3	ST	245,000	297,000	10.3	38.8
4	ST	245,000	297,000	10.3	35.4
5	L	246,000	297,000	9.0	25.9

*Location of test specimens shown in Fig. 2.
†ST: short transverse direction; L: longitudinal direction.
‡Gage length = 4 × diameter of test bar.

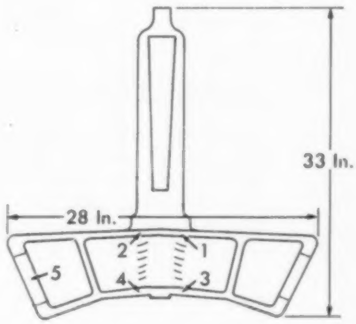


Fig. 2 – Positions From Which Test Specimens Were Taken in Vertical Spindle Die Forging of Aft Fuselage Frame of A3J-1. Numbers indicate ends of the test bars

Table III – Mechanical Properties of Air-Melted and CEVM H11 Steel Horizontal Spindle Die Forgings

Bar Number*	Yield Strength, Psi.	Ultimate Tensile Strength, Psi.	Elongation†, %	Reduction in Area %
		Air-Melted‡		
1	234,000	287,000	4.7	8.2
2	237,000	280,000	1.5	4.0
3	234,000	281,000	1.3	5.1
4	236,000	283,000	1.9	4.5
		Consumable-Electrode, Vacuum-Melted‡		
1	240,000	294,000	9.3	24.6
2	238,000	292,000	7.5	21.4
3	241,000	295,000	9.5	24.1
4	248,000	297,000	8.8	31.2

*Location of test specimens shown in Fig. 3.
†Gage length = 4 × diameter of test bar.
‡All specimens oriented in short transverse direction.

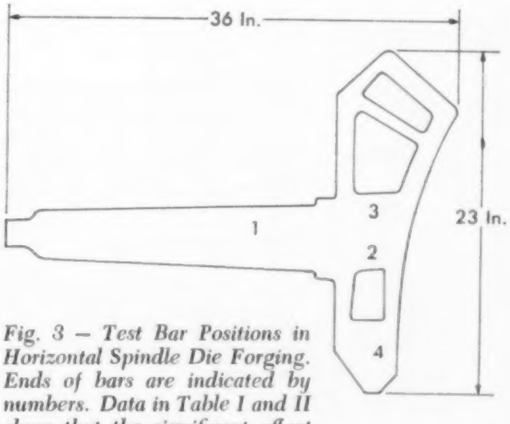


Fig. 3 – Test Bar Positions in Horizontal Spindle Die Forging. Ends of bars are indicated by numbers. Data in Table I and II show that the significant effect of vacuum melting is that it improves reduction in area. Elongation is also improved

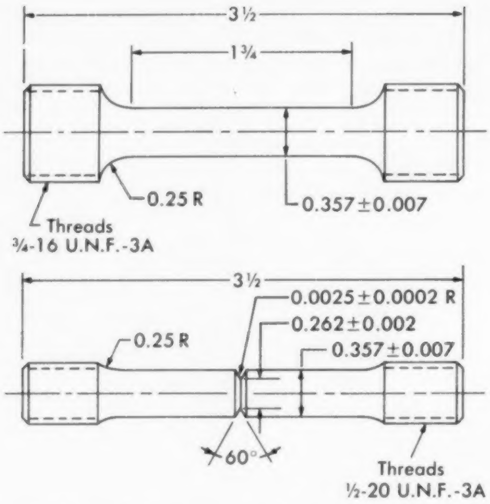


Fig. 4 – Test Bars Used to Determine Effect of Tempering Temperature on Notched and Smooth Tensile Properties of Air-Melted and Consumable-Electrode, Vacuum-Melted H11 Steel. All specimens were austenitized at 1850° F. for 1 hr. and triple tempered, each for a total of 6 hr., at various temperatures. Figures 5 and 6 show the results

transverse ductility with less directionality in mechanical properties for the CEVM material.

Consumable-electrode, vacuum melting reportedly achieves substantial improvement in cleanliness for these reasons: Molten metal does not contact the refractory crucible and slag; oxides and nitrides dissociate in the arc; those compounds which do not dissociate are levigated and dispersed in the molten metal. In general, the number of nonmetallic inclusions in CEVM material is less than in air-melted H11, but the difference is not as pronounced as might be expected. Air-melted H11 is produced using "tool steel" electric-furnace melting practice with special attention directed to cleanliness. As a result, the nonmetallic inclusion content of air-melted material is generally low. This could account for the lack of outstanding difference in cleanliness. More important in rendering inclusions less harmful to mechanical properties may be their size, shape and distribution. It would appear that the most significant factor in the ability of CEVM to improve transverse ductility and uniformity of H11 stems from the controlled solidification of the ingot in a water-cooled crucible, a technique which produces an exceptionally sound and homogeneous material. This is particularly advantageous for materials, such as H11, which are prone to segregation because of appreciable alloy content. To achieve good transverse mechanical properties, the importance of a high-quality ingot cannot be overemphasized. Although some degasification occurs during CEVM, the significance of the lower gas content as it affects transverse ductility has not been well established.

Effect of Tempering Temperature

An investigation was also conducted to determine the effect of tempering temperature on the smooth and notched tensile properties of CEVM H11 compared to air-melted material. Standard subsize tensile specimens and notched tensile specimens were rough machined from 1-in. diameter air-melted bar and CEVM mate-

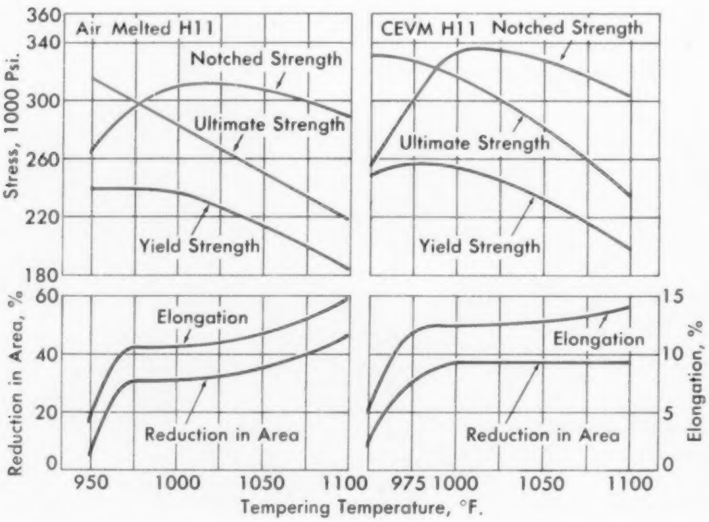


Fig. 5 – How Tensile Properties of Air-Melted and Consumable - Electrode, Vacuum - Melted H11 Tool Steel Vary With Tempering Temperature. Although CEVM material shows higher yield and ultimate strengths, the difference is apparently due to chemistry. Elongation and reduction in area of CEVM H11 are, however, superior to those of air - melted material

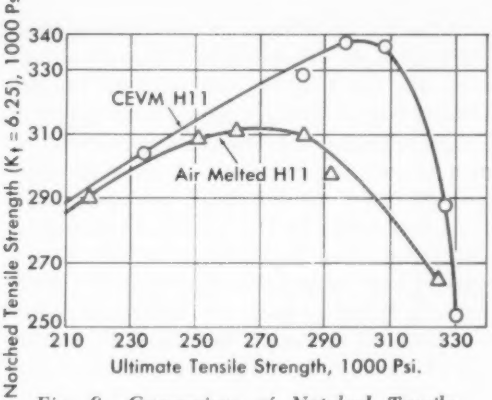


Fig. 6 – Comparison of Notched Tensile Strength With Ultimate Tensile Strength of Air-Melted and Consumable-Electrode, Vacuum-Melted H11 Demonstrates That the Latter Is Less Sensitive to Notches, Particularly at Strength Levels Above 260,000 Psi.

rial. The specimens were austenitized at 1850° F. for 1 hr. in a neutral salt bath, air cooled to room temperature, and triple tempered (2 hr. + 2 hr. + 2 hr.) at various tempering temperatures. All specimens were finish ground after heat treatment.

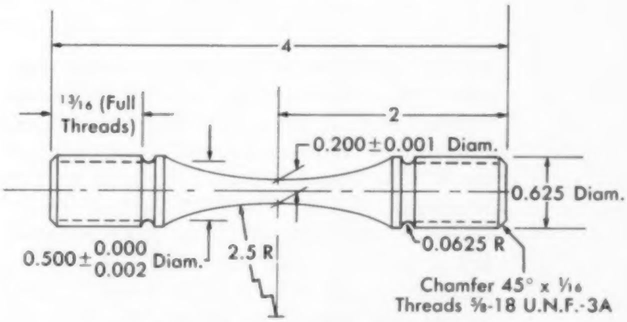
Configuration of specimens is shown in Fig. 4. The geometry of the notched tensile specimen provided a stress concentration factor, K_t, of 6.25. Results of the tensile tests are shown in Fig. 5. No particular significance can be attached to the better response to heat treatment by CEVM material because the higher yield and ultimate strength for a given tempering temperature is apparently due to differences in chemical composition between the two heats. The most significant difference between CEVM and air-melted H11 is the superiority of the former with respect to notched tensile strength, particularly at tensile strengths above 260,000 psi. A plot of these data (notched tensile strength as a function of ultimate tensile strength) more clearly indicates this difference as shown in Fig. 6. It can be seen that CEVM H11 steel is definitely less notch sensitive than air-melted H11 at strengths above 260,000 psi.

Vacuum Melting Improves Fatigue Life

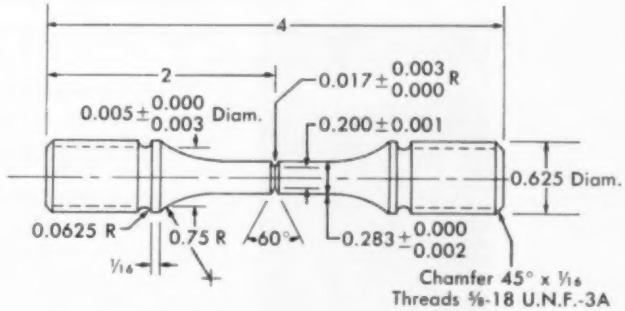
A comparative study of some fatigue properties of air-melted and CEVM H11 steels was also conducted. Unnotched and notched axial load fatigue specimens were machined from the 1-in. diameter CEVM H11 bars used for the static notched strength specimens just described. The specimen configurations are shown in Fig. 7. Critical sections of the specimens were polished. The 60° V-notch provided a stress concentration, K_t, of 2.4. Similar specimens had previously been tested from the midradius of an air-melted 5-in. diameter bar of H11 steel. All longitudinal specimens, heat treated to a tensile strength of 280,000 to 300,000 psi., were employed for comparison tests. Axial load fatigue tests with a stress ratio, R, of 0.02 were conducted on the four series of specimens in a Sonntag SF-10U fatigue machine. Results of these tests are presented in Fig. 8 as plots of maximum stress (percent of ultimate tensile strength) versus minimum life.

The improvement shown by the CEVM un notched specimens over the air-melted H11 steel for endurances greater than about 3×10^4 cycles is considerable. In the notched condition, there is an essentially constant improvement at all endurance limits for the CEVM H11 steel over the air-melted material. The difference between the endurance limits of

Fig. 7 – Specimen Geometries Shown Here Were Used in Tests to Determine Fatigue Properties of Air-Melted and Vacuum-Melted H11 Tool Steel



Unnotched Axial Load Fatigue Specimen



Notched Axial Load Fatigue Specimen (K_t = 2.4)

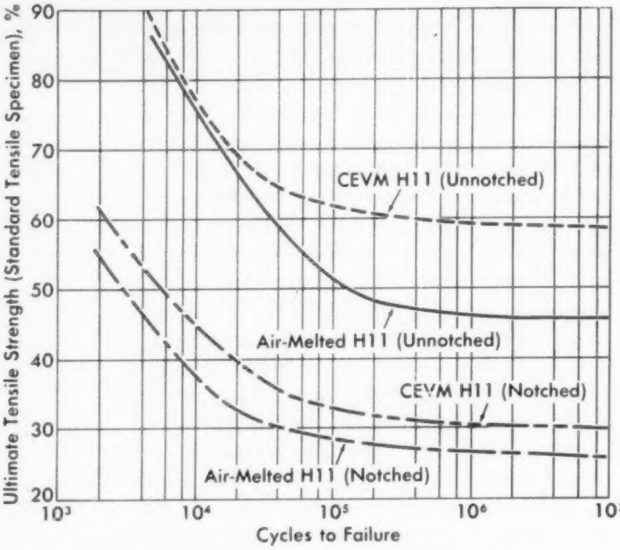


Fig. 8 – Results of Tests Show Superior Fatigue Strength of Consumable Electrode, Vacuum-Melted H11. Air-melted specimens were taken from midradius (longitudinal direction) of 5-in. rounds and were heat treated to 295,000 psi. ultimate tensile strength. Vacuum-melted specimens came from 1-in. bars (longitudinal direction) and were heat treated to an ultimate tensile strength of 290,000 psi. Stress ratio (R) = 0.02. Test-bar geometry is shown in Fig. 7.

smooth specimens of the two materials compares well with the similar data for 4340 steels reported by F. B. Stulen (see "Effect of Material Property Variations on Fatigue", *Proceedings* of the WADC Symposium on Fatigue of Aircraft Structures, WADC TR59-507, August 1959). However, the notched data do not agree. Stulen postulates that the equivalent notched fatigue strengths of the air-melted and vacuum-melted 4340 steels is the result of the comparatively equal cleanliness of the very limited, highly stressed volume under the notch in both materials, but that the difference in the unnotched fatigue strength is due to the improved average cleanliness in the vacuum-melted 4340 steel of the larger volume of material under peak stresses in the unnotched specimen. Since the data obtained for H11 steel in the present investigation shows improvement in both the unnotched and notched conditions for the CEVM material, there are evidently additional factors involved. As previously described, the cleanliness of the air-melted material approaches that of the CEVM stock. Therefore, it appears that the homogeneity and uniform dispersion of inclusions in the latter material may be significant factors contributing to the improved fatigue strength in both the unnotched and notched conditions. In view of the homogeneity in the CEVM H11, it is unlikely that the fatigue properties of specimens from the midradius of CEVM H11 bar, 5-in. in diameter, would be significantly different from those obtained with the 1-in. diameter rod. A current program involving stock in this size range is expected to verify this assumption.

In conclusion, CEVM H11 steel has greatly superior transverse ductility (elongation and reduction of area) and better uniformity in tensile properties than air-melted material. In general, CEVM material is cleaner than air-melted H11 but the size, shape, and distribution of the inclusions in CEVM may be more important in minimizing harmful effects than quantitative differences. Consumable-electrode vacuum melting gives much higher notched tensile strengths than does air melting at tensile strengths above 260,000 psi. It also improves both notched and unnotched axial fatigue strength.

on the Cover

Snowflakes on the Grass

Though the fanciful title above describes the cover for our December issue very well, the micrograph actually illustrates (at 50 ×) Type 356, an aluminum casting alloy. Made by Clayton McNeil, Chrysler Corp., and entered in the 15th Annual A.S.M. Metallographic Exhibit, it reveals the microstructure of an experimental valve for the liquid oxygen system in the Jupiter missile. The "snowflakes" are dendrites; in giving an indication of the casting rate, they help to establish proper gating and casting techniques for the valve. The small, dark constituents in the photo outline an interdendritic network of silicon and associated needles of beta (Al-Fe-Si). The etchant is 0.5% HF in alcohol.

The Effects of Strain Rate and Temperature on Metals

*By J. R. KATTUS**

Metals increase in strength under an increasing rate of strain; this effect becomes quite large at elevated temperatures. Under conditions of rapid loading and short times at temperature, strengthening mechanisms – such as precipitation and work hardening or martensitic transformation – retain some of their effectiveness to much higher temperatures. (Q27, 3-68, 3-61)

Southern Research Institute has been investigating elevated-temperature mechanical properties of metals under conditions of rapid strain rate and short times at temperature. This information is useful in designing structural members for missiles and spacecraft which must withstand similar conditions.

In an extensive evaluation, three sheet materials – Alclad 7075-T 6 aluminum, A110AT titanium, and a hot work die steel – plus a cast alloy, ZH62-T 5 magnesium, were tested at four temperatures.

Two strain rates were studied: 0.00005 in. per in. per sec., which is a normal rate requiring several minutes to rupture, and 1.0 in. per in. per sec., which is a fast rate requiring less than 1 sec. to rupture. All test specimens were heated to testing temperature within 10 sec. and held at temperature for ½ hr. before being loaded to failure.

The four stress-strain curves obtained (Fig. 1 through 4) show the increase in tensile strength as strain rate is increased. Although this effect appears inherent, it is counteracted in some alloys within limited temperature ranges by structural changes such as strain aging or precipitation. Total elongation does not correlate consistently with changes in temperature or with changes in strain rate. In general, uniform elongation (elongation up to ultimate load) decreases with increasing temperature due to the decreasing degree of work hardening. The effect of increasing strain rate (on uniform elongation) is quite inconsistent.

Relative Effects of Strain Rate

As shown in Fig. 5, strain rate has a relatively minor effect on tensile strength at room temperature. At higher temperatures, the effect of strain rate becomes much greater; the

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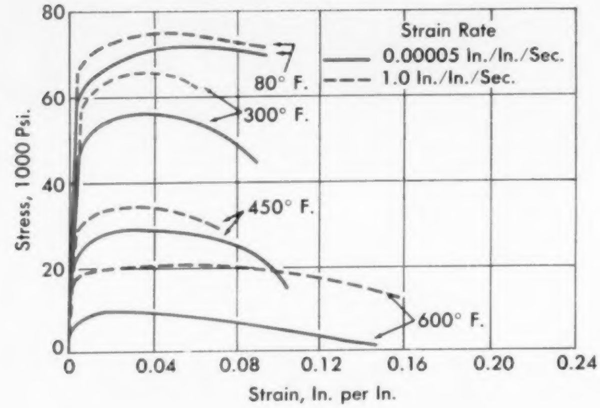


Fig. 1 – Stress-Strain Curves for Alclad 7075-T 6 Aluminum Sheet at Different Temperatures and Strain Rates. Composition: 1.6 Cu, 2.5 Mg, 5.6 Zn, 0.3 Cr, balance Al

strength properties rise markedly with higher strain rate. This increase (for each alloy) begins rather abruptly at a specific temperature which corresponds roughly to the recrystallization temperature. In addition to increased strain rate sensitivity, high-temperature behavior (above the recrystallization point) is characterized by a breakdown of low-temperature strengthening mechanisms as a result of a higher rate of self-diffusion. Poor resistance to creep and an inability of metals to work harden are invariably associated with high-temperature behavior. Therefore, the temperature of transition is normally the maximum temperature for load-carrying applications involving longer times.

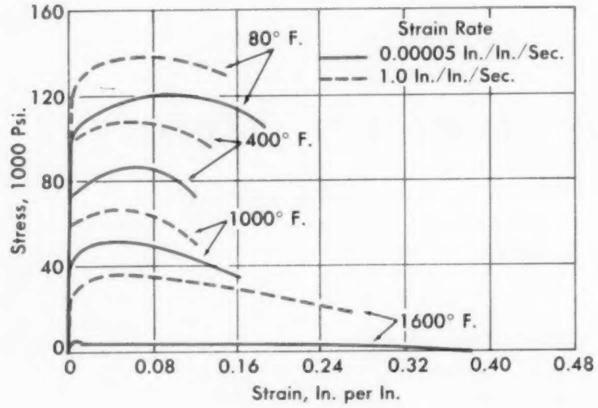


Fig. 2 – Stress-Strain Curves for Annealed A110AT Titanium Sheet at Different Temperatures and Strain Rates. Composition: 5.7 Al, 2.7 Sn, 0.1 Cu, 0.02 N, balance Ti

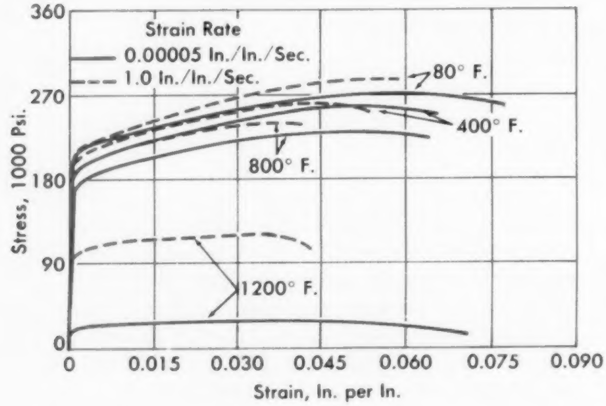


Fig. 3 – Stress-Strain Curves for Quenched and Tempered Hot Work Die Steel Sheet at Different Temperatures and Strain Rates. "Peerless 56" composition: 0.40 C, 0.56 Mn, 0.99 Si, 0.011 S, 0.020 P, 3.25 Cr, 2.57 Mo, 0.26 V, balance Fe

Tensile properties at slow rates of strain deteriorate considerably because of the transition to high-temperature behavior. At high rates of strain (under high-temperature conditions) higher strength properties are maintained, probably because plastic flow occurs more rapidly than diffusion. Therefore, structural metals can be used safely at higher temperatures under conditions of rapid loading.

Alloys best suited for high-temperature applications on the basis of creep properties may not provide the best structural strength in missiles and aircraft at certain temperatures when loads are applied rapidly and for short periods

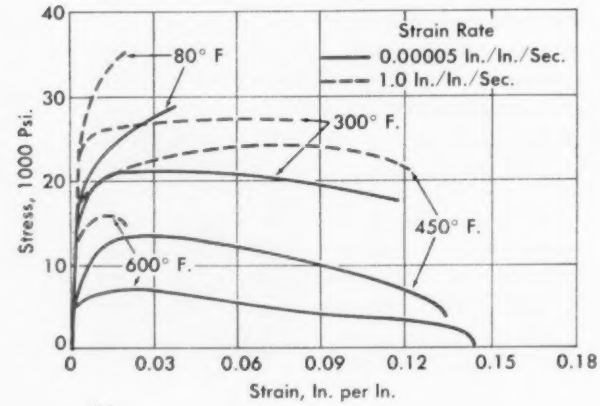


Fig. 4 – Stress-Strain Curves for Cast ZH62-T 5 Magnesium Alloy at Different Temperatures and Strain Rates. Composition: 6.2 Zn, 2.1 Th, 0.9 Zr, 0.03 Si, 0.03 Al, 0.01 Cu, 0.001 Ni, balance Mg

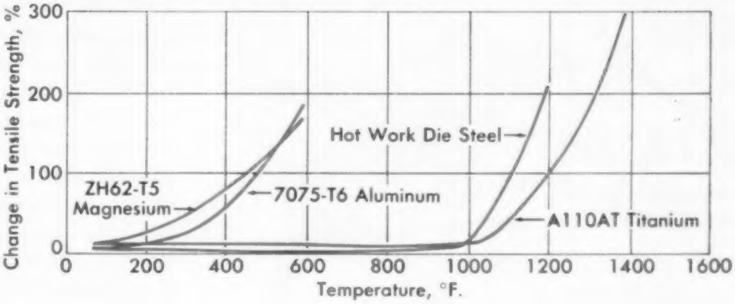


Fig. 5 – Effect of Temperature on Percentage Change in Tensile Strength Resulting From Strain-Rate Increase (0.00005 to 1.0 in. per in. per sec.) Above the recrystallization temperature, strain rate has an increasing effect on properties

of time. This point is illustrated in Fig. 6 which shows the effect of strain rate on the strength of a hot work die steel and Inconel "X" (Inconel alloy X-750) at 1000, 1200 and 1400° F. after holding 30 min. at temperature. At 1200° F., the die steel exhibits greater strain-rate sensitivity, indicating high-temperature behavior, whereas Inconel "X" (Inconel alloy X-750) exhibits low-temperature behavior. As a result, the strength curves cross at a strain rate in the range of tensile loading. At 1200° F., therefore, Inconel "X" (Inconel alloy X-750) provides the better strength for applications involving creep and slow tensile loading, whereas the die steel provides the better strength for applications involving rapid tensile loading and impact.

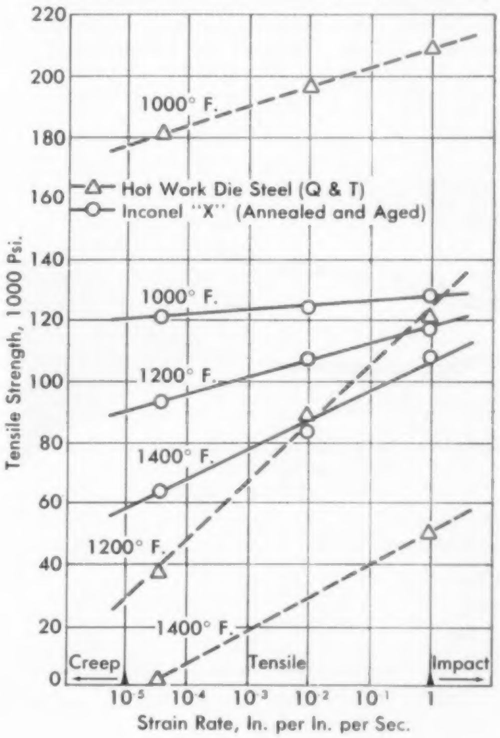
Metallurgical Structure Affects Properties

Figure 7 illustrates the effects that temperature and strain rate have on strengthening mechanisms for steel (cold work or heat treatment). The tensile strength ratios of a hardened structure to an unhardened structure are plotted as functions of temperature for two strain rates. Strengthening mechanisms are effective in the range of low-temperature behavior but deteriorate in the range 800 to 1200° F. (transition to high-temperature behavior). An important point brought out by these curves is that, at the faster strain rate, the low-temperature strengthening mechanisms are effective to higher temperatures.

In Type 301 stainless, fully work-hardened material is slightly stronger than half-hard material at temperatures up to 800° F. regardless of strain rate. At 1200° F., the strength superiority of the full-hard material decreases almost to zero regardless of strain rate, the effect of strain rate on this deterioration being negligible. The absence of strain-rate effects can be attributed to the fact that the softer material is partially hardened rather than dead soft. The strength of both materials are derived from the same mechanisms; therefore, increasing strain rate has the same relative effect on both materials at all temperatures.

In 17-7 PH and the 4130 steels, the metallurgical structures in the heat treated condition are considerably different from those in the annealed state. In the temperature range 800 to 1200° F., the strengthening mechanisms of the fully heat treated structures deteriorate much more than those of the soft structures,

Fig. 6 – Effect of Strain Rate on Tensile Strength of Die Steel and Inconel "X" (Inconel Alloy X-750) Sheet at Various Temperatures. This shows that an alloy with highest creep properties may not provide best high-temperature structural strength under conditions of rapid loading



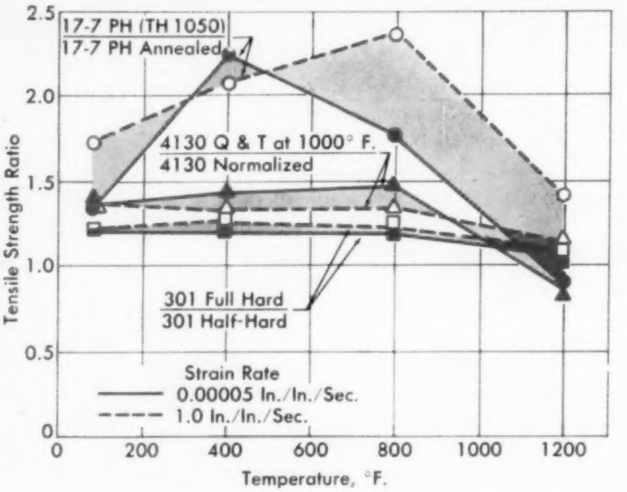
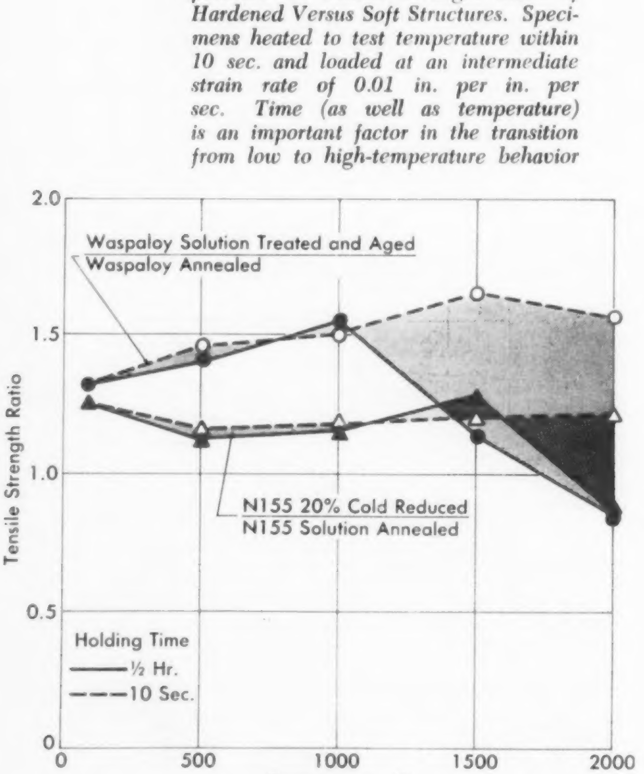


Fig. 7 – Effect of Temperature and Strain Rate on Tensile Strength Ratio of Hardened Versus Soft Structures. Specimens held at temperature 30 min. before testing. Note that strengthening mechanisms are effective only below transition temperature

Fig. 8 – Effect of Holding Time at Temperature on Tensile Strength Ratio of Hardened Versus Soft Structures. Specimens heated to test temperature within 10 sec. and loaded at an intermediate strain rate of 0.01 in. per in. per sec. Time (as well as temperature) is an important factor in the transition from low to high-temperature behavior



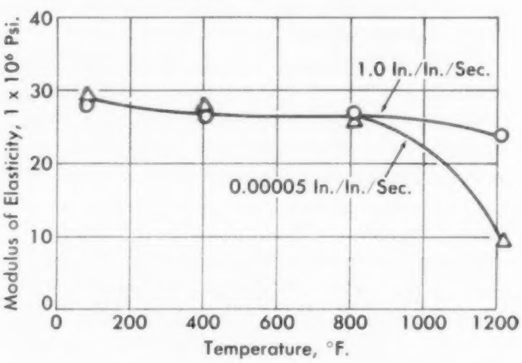
especially at the slow strain rate. At the fast strain rate, the strengthening mechanisms of the fully heat treated structures are still effective in hindering plastic strain, and the hardened structures retain some superiority in strength over the soft structures. These effects of strain rate are consistent with the previously stated fact that at fast strain rates metals tend to retain low-temperature strength characteristics to higher temperatures than they do at slow strain rates.

The influence of holding time at temperature prior to tensile testing on the effectiveness of various hardening treatments is shown in Fig. 8. Time, temperature, and strain rate are important factors in the transition from low to high-temperature behavior. The breakdown of low-temperature strengthening mechanisms – deterioration of precipitation hardening by coagulation and growth or disappearance of work hardening by recrystallization – takes time even at high temperature.

The Modulus of Elasticity

The effect of temperature and strain rate on the modulus of elasticity of a hot work die steel is shown in Fig. 9. The "apparent" decrease in modulus at a slow strain rate and at temperatures above 800° F. is due to a small amount of plastic deformation (creep) that occurs during the initial phase of the tensile test as the specimen is loaded slowly through the elastic region. This plastic deformation decreases the slope of the stress-strain curve causing a decrease in modulus value. Since creep is time dependent, the modulus determined at a rapid strain rate is representative of true elasticity. In the range of low-temperature

Fig. 9 – Effect of Temperature and Strain Rate on Modulus of Elasticity of Quenched and Tempered Hot Work Die Steel Sheet



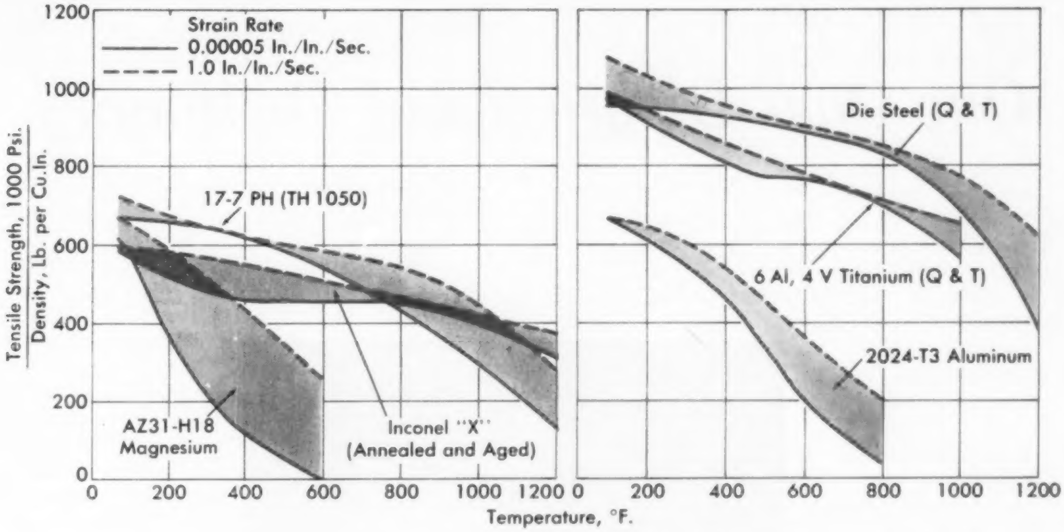


Fig. 10 – Effect of Temperature on Strength-Weight Ratio of Some Structural Sheet Metals at Two Strain Rates. Inconel "X" (Inconel alloy X-750), with lowest ratio at room temperature, holds up better under increasing temperatures; it is exceeded only by the strength-weight ratio of die steel at 1200°F.

behavior, modulus values are unaffected because creep is negligible.

Effect on Strength-Weight Ratio

Figure 10 shows the effects of temperature (holding time: 10 sec.) and strain rate on strength-weight ratios of several structural alloys. At room temperature, the highest ratios are found in the quenched and tempered die steel and in the quenched and tempered 6 Al, 4 V titanium alloy; up to 1200° F., the die steel is superior in this property. The strength-weight ratio of Inconel "X" (Inconel alloy X-750), which is lowest at room temperature, does not decrease as rapidly with increasing temperature; at 1200° F., it is exceeded only by the strength-weight ratio of the die steel. Although not shown in the figure, a further increase in temperature to 1400° F., or long holding times at 1200° F., decrease the relative superiority of the die steel because of its instability at these temperatures. Under these conditions, Inconel "X" (Inconel alloy X-750) is superior at the slow strain rate, but the die steel retains superiority at the fast strain rate (see Table I).

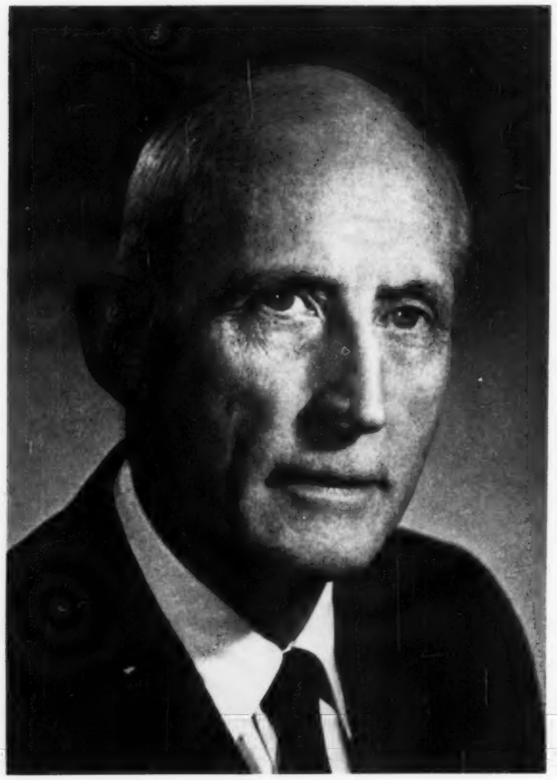
At room temperature, the strength-weight ratios of 17-7 PH, 2024-T 3, and AZ-31 are similar. At elevated temperatures, however, the stainless steel is superior to the aluminum and magnesium alloys.

Table I – Strength-Weight Ratios of Die Steel and Inconel "X" (Inconel Alloy X-750)

Testing Temperature	Time at Temperature	Strain Rate	Material	Strength-Weight Ratio*
1400° F.	10 sec.	1.0 in./in./sec.	Inconel "X"	325
1400	10	0.00005	Inconel "X"	215
1400	10	1.0	Die steel	390 (extrapolated)
1400	10	0.00005	Die steel	75 (extrapolated)
1200	30 min.	1.0	Inconel "X"	360
1200	30	0.00005	Inconel "X"	290
1200	30	1.0	Die steel	425
1200	30	0.00005	Die steel	230

*Ultimate tensile strength, 1000 psi. / Density, lb. per cu.in.

Our Own Biographical Dictionary



John Burlin Johnson
An Eminent American Metallurgist

JOHN BURLIN JOHNSON, or "J.B.", as he is known to friends far and wide, has spent literally a lifetime in aviation, in improving aircraft engines and structures. Here is the chronology:

1916 to 1918–Inspector, airplanes and engines, Aviation Section, Signal Corps (Washington).

1918 to 1923 – Army Air Corps, Assistant Chief of Materials Laboratory, McCook Field (Dayton).

1923 to 1948 – Chief of Materials Laboratory, Engineering Div., Wright Air Development Center (Dayton).

1949 to 1954 – Chief, Metallurgy Research Branch, Office of Air Research (Dayton).

1954 to 1958 – Technical Director, Aeronautical Research Laboratory, Wright-Patterson Air Force Base (Dayton).

The progression shown in this list of titles is enough to indicate a long list of successes. He has had a guiding hand in the development of innumerable procedures for testing materials and controlling fabrication processes for military aircraft.

John Johnson was born May 31, 1890 at Olean, N.Y., attended high school there and then went on to Cornell University where he earned a degree of mechanical engineer in 1912.

His life work started almost immediately: In his first work with the Signal Corps, "J.B." recognized that sampling of commercial lots and selection of those lots which gave the best tests – then the accepted procedure for wood, fabric, lubricants – was not good enough for steel. Each metallic part had to be inspected for inherent quality. For this, he and Alfred de Forest worked out the principles and working procedures for magnetic inspection. Since then his interest in nondestructive testing has never flagged.

In the 1920 decade, welding was emerging from a repair operation to a production method; he saw its possibilities immediately and made so many constructive suggestions that they eventually bulked into a 400-page book entitled "Airplane Welding and Materials". For this he was awarded the 1929 Morehead Medal by the International Acetylene Association.

A pressing problem early in World War II was the conservation of strategic alloys. With rare foresight, he had already started work along these lines at Dayton and the data secured had great influence in establishing the 4100 series of steels (low in chromium and molybdenum) widely favored for welded structures, the deep hardening 4300 series (nickel-chromium-molybdenum), and the utilization of the low-alloy "National Emergency Steels" in military aircraft. In recognition of these achievements the Secretary of War presented Mr. Johnson the Emblem for Exceptional Meritorious Services.

He was interested in stainless and heat-resistant steels for aircraft at least 20 years before they became necessary for supersonic aircraft and jet engines. As early as 1930 he started work on high-temperature alloys for power plants, and for such work as this he received the Thurman Bane Award from the Institute of Aeronautical Sciences. Other examples of planning for future needs are his interest in aluminum and magnesium alloys for structural and skin materials (even when the "flying crates" were made of wood, fabric and wire), in beryllium (starting in 1938), and in titanium and zirconium (1946). In 1949 he established a special department of the Aeronautical Research Laboratory at Wright-Patterson Air Force Base for the study of metal and oxide combinations for ultra high-temperature service.

This is not all, but enough has been cited from the full record to warrant in 1960 the award of the Gold Medal of the American Society for Metals, established in 1943 "to recognize outstanding metallurgical knowledge and great versatility in the application of science to the metal industry, as well as exceptional ability in the diagnosis and solution of diversified metallurgical problems". No one acquainted with the history of American aviation, both civilian and military, could find a man who better fits that specification.

Mr. Johnson was married to Marian Ochiltree in 1922 and has had two children. His personal hobbies are gardening and golf.

Aside from the indications of intellectual competence and prophetic vision cited earlier in this biographical appreciation, Mr. Johnson has an outstanding record of sharing his knowledge with others. He has been a member of the American Society for Metals for 33 years, during which time he served as National Trustee, 1951 to 1953, and Chairman of the Handbook Committee, 1948 to 1951. He was chairman of the Aeronautical Material Specifications Div. of the Society of Automotive Engineers for 18 years. He participated in the activities of the National Advisory Committee for Aeronautics over a period of 23 years, and in various Army Ordnance committees for 20 years. Thirty years measures his membership in the American Society for Testing Materials.

Throughout Wright-Patterson Air Force Base and the American aeronautical industry, John Burlin Johnson is known as a man who takes a logical approach to a knotty problem. His ability to analyze the auxiliary aspects of a main question is uncanny. His example has been a personal inspiration to all his associates. These qualities were recognized by the Society in bestowing its Gold Medal, and by us in presenting this biographical appreciation.

ERNEST E. THUM

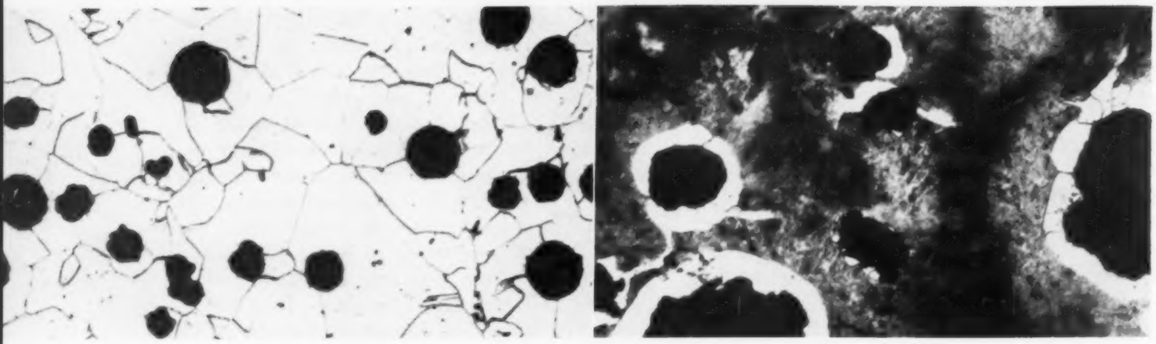


Fig. 1 – Variations in Microstructure of Experimental Cast Irons. The iron containing high silicon (4.12%) and low manganese (0.26%) has the smallest graphite spheroids in a ferritic matrix, while that with medium silicon (2.62%) and high manganese (1.10%) has large spheroids surrounded by "bull's-eye" ferrite in a pearlite matrix. Etchant: 3% Nital; 250 ×

How Composition Affects the Properties of Ductile Iron

*By J. F. WALLACE and L. J. EBERT**

In the heat treatment of ductile iron, silicon increases the critical temperature range and enhances the tempering response, while manganese decreases the critical temperatures, improves hardenability and reduces tempering response. By selecting the proper heat treatment, irons with extremely high tensile and yield strengths can be produced with moderate ductilities.
(J-general, Q-general, 2-60; CI-r)

DUCTILE IRON RESPONDS well to heat treatment. In fact, by varying the austenitizing temperatures, cooling rates and compositions, the combined carbon in the matrix can be varied from zero to over 1% to provide a wide range of hardness, strength, and ductility. However, there is a complication. Alloying elements in the iron, including silicon and manganese, have a profound effect on the resulting properties. Because this phenomenon has caused users of ductile iron some problems in consistently developing desired properties in varying lots of given grades, we undertook this research.

*Professor and Associate Professor, respectively, Department of Metallurgy, Case Institute of Technology, Cleveland. The research reported here was sponsored by the Gray Iron Founders' Society, Cleveland.

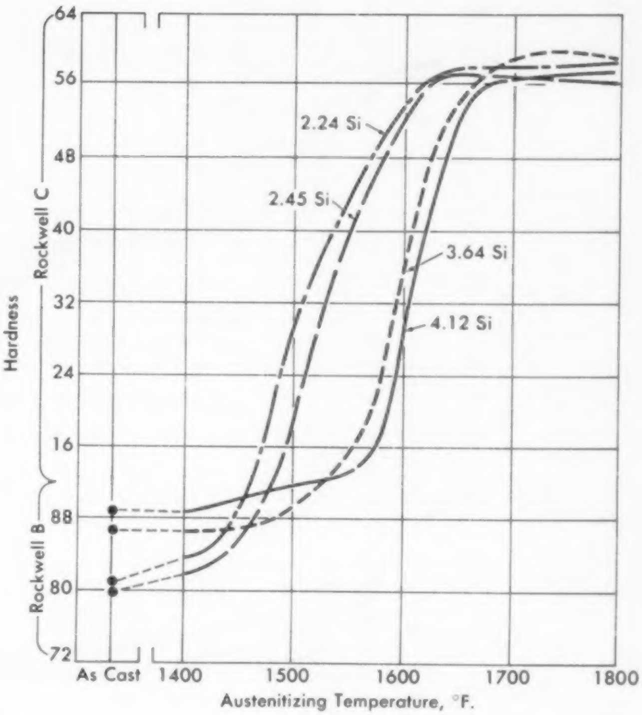
Heat Treating Effects Studied

In planning this research program we considered several factors. For example, we knew

Table I – Austenitizing Temperatures of Experimental Irons

Silicon	Manganese	Austenitizing Temperature
2.24%	0.26%	1650°F.
2.45	0.26	1650
3.64	0.26	1675
4.12	0.26	1700
2.36	0.68	1600
2.62	1.10	1550

Fig. 2 – Effect of Silicon Content and Austenitizing Temperature on As-Quenched Hardnesses of Experimental Cast Irons. With increasing silicon, both critical temperatures rise, the lower more than the upper. In these irons, carbon is about 3.75% and manganese is 0.26%



that the hardenabilities of steels and irons could be improved at relatively low cost by adding manganese. (On the other hand, ductile irons with higher manganese contents often contained some massive carbides formed during solidification, particularly in thin sections. This is undesirable.) High silicon contents were also wanted; silicon strengthens ferrite, improves resistance to growth and scaling, and reduces possibility of carbides forming in thin sections.

With these factors in mind, six castings (representing two series of compositions) of ductile iron were made for the study. Four of them represented a range of silicon contents (2.24, 2.45, 3.64 and 4.12%), while three castings constituted a series in which the manganese content varied (0.26, 0.68 and 1.10%). Though silicon showed slight variation (from 2.36 to 2.62%) in the latter series, this had no significant effect.

As for the as-cast microstructures of the six irons, graphite was generally in spheroidal form. Spheroid size varied somewhat, the finest being in the 3.64 and 4.12% Si irons and the coarsest in the 1.10% Mn iron. Figure 1 illustrates the range in sizes and the slight variation in shapes in the as-cast matrix structures. As is evident, the higher-manganese irons (represented by the 1.10% Mn material) had a matrix of pearlite with "bull's-eye" ferrite around the graphite spheroids, while the higher-silicon irons, 3.64 and 4.12%, had matrices which were entirely ferritic.

Heat Treatment Temperatures Determined

Initially, we determined the upper and lower critical temperatures for each composition to aid in establishing proper treatments for austenitizing and tempering. To do this, we heated small blocks of each experimental composition to various temperatures between 1400 and 1800° F., quenched them in water, and checked their hardnesses. Results are shown

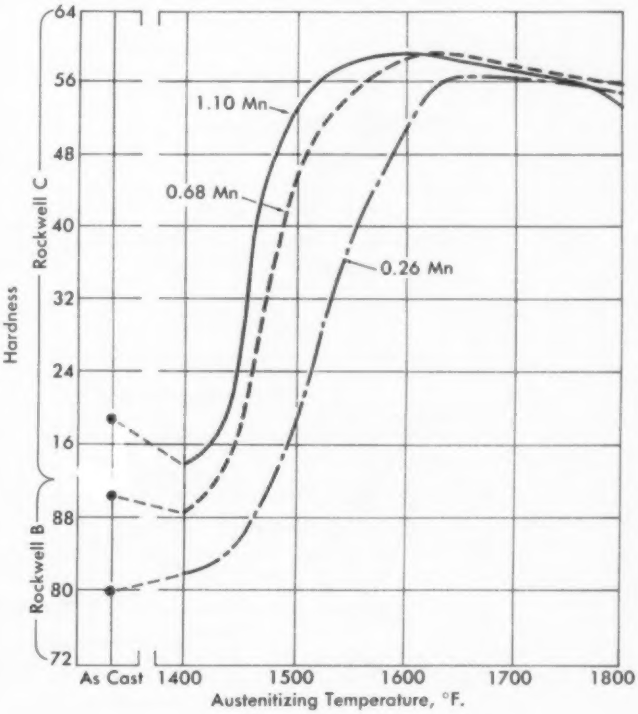


Fig. 3 – Effect of Manganese Content and Austenitizing Temperature on the As-Quenched Hardnesses of the Experimental Irons. With increasing manganese, the upper and lower critical temperatures drop. Carbon, 3.75%; silicon 2.45%

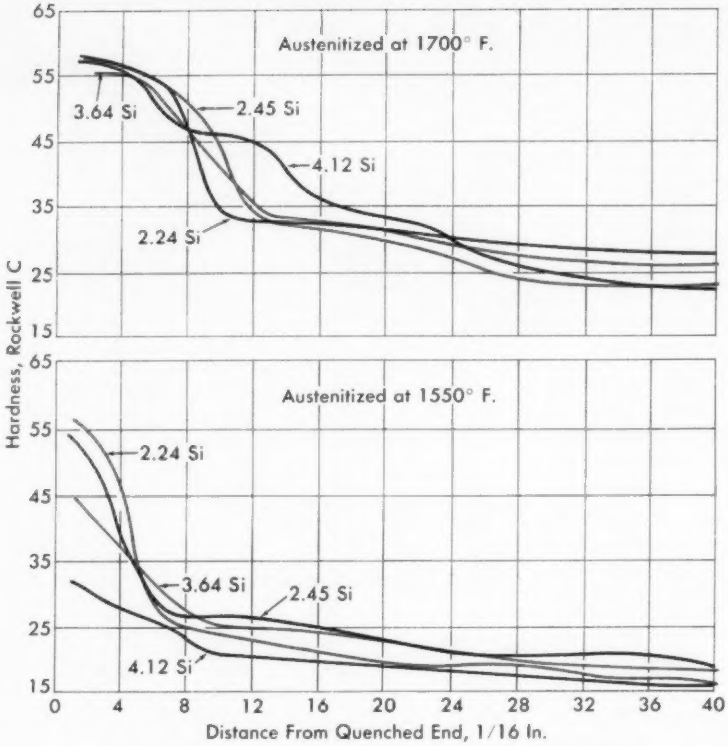


Fig. 4 – End-Quench Hardenabilities of Experimental Irons With Different Silicon Contents. Note that full hardenabilities are obtained only in irons austenitized at the higher temperature, and that higher silicon increases the hardenability slightly

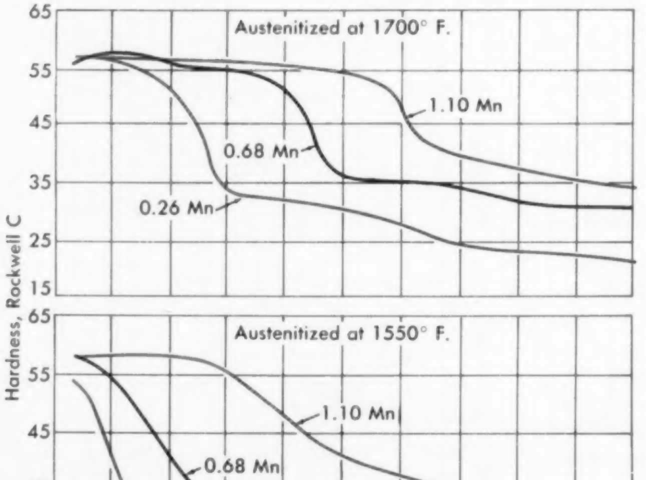
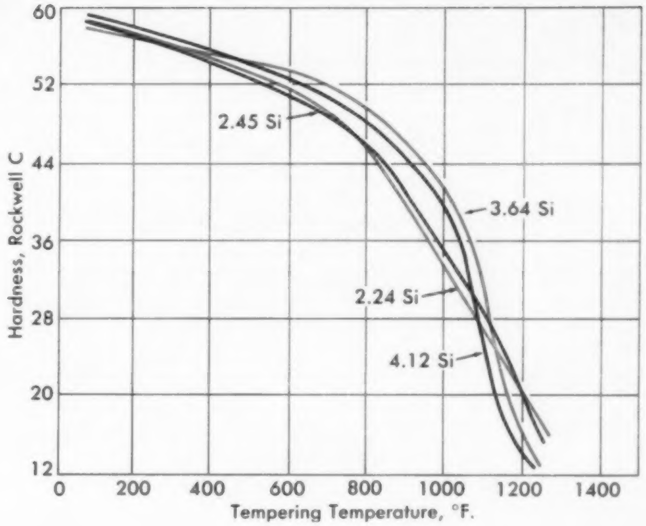


Fig. 5 – End-Quench Hardenabilities for the Irons With Varying Manganese Contents. As is apparent, the addition of manganese increases the hardenability appreciably

Fig. 6 – *Temperabilities of the Irons With Varying Silicon Contents. Note that higher silicon irons are harder at a given tempering temperature, and that hardnesses drop rapidly in high-silicon irons tempered above 1000° F. Carbon, 3.75%; manganese, 0.26%*



in Fig. 2 and 3 as a function of the austenitizing temperature.

It might be well to explain the appearance of these curves. To begin with, the microstructures consisted entirely of austenite and graphite at heating temperatures represented by the upper plateaus (Fig. 2 and 3). On heating the test blocks, the graphite in the as-cast structures gradually dissolved so that phases in heated material represented austenite, ferrite and graphite, the amount of austenite increasing with rising temperature. When the heated blocks were quenched, the austenite transformed to martensite; this accounts for the greater hardness with higher heating temperatures. The decrease in hardness with increasing temperature at the upper level, where presumably the structure was entirely austenite and graphite, is caused primarily by retained austenite.

In using the curves shown in Fig. 2 and 3, the points of inflection for the upper and lower plateaus were considered as the upper and lower critical temperatures, respectively. As Fig. 2 shows, both temperatures rose with the silicon contents; but the rate at which the upper

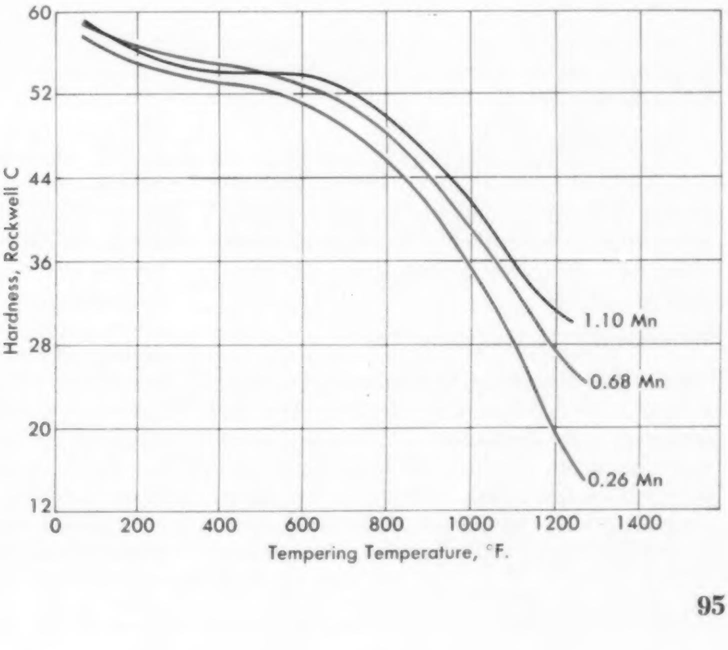


Fig. 7 – *Effect of Tempering on Hardnesses of Manganese-Series Irons. In general, manganese slows tempering response and has a greater effect on the resulting hardnesses than silicon. Carbon, 3.75%; silicon, 2.45%*

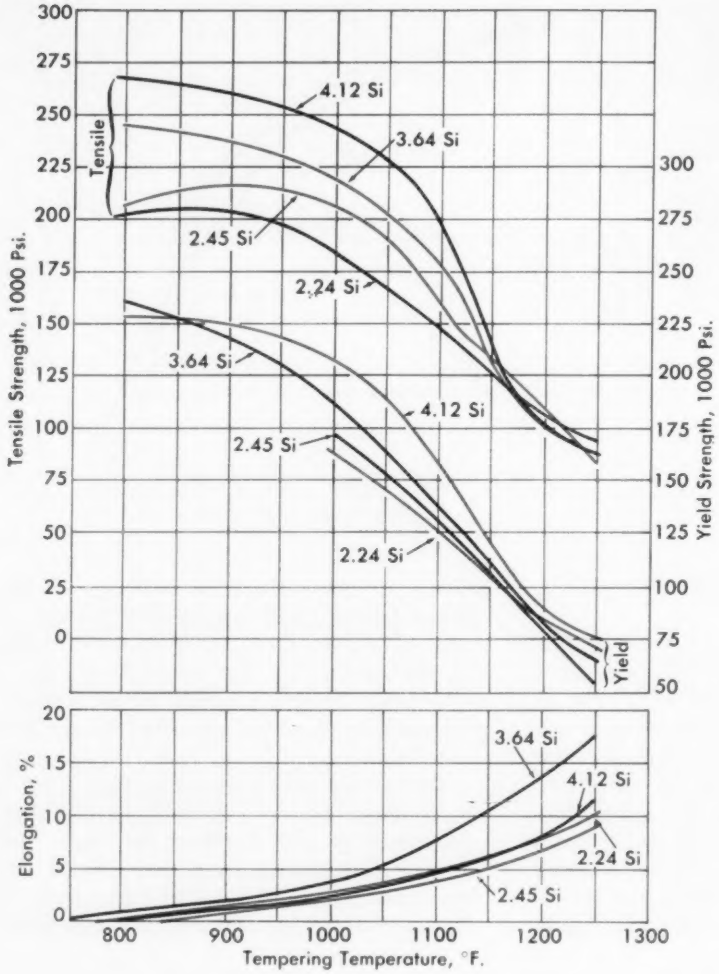


Fig. 8 – Tensile Properties of Irons Containing Varying Silicon Contents. Note that strength rises with silicon contents for the lower tempering temperatures, but that this effect gradually fades away as the tempering temperature rises. Carbon, 3.75%; manganese, 0.26%

critical temperature rose was less than that of the lower critical. Because of this, the range between the critical temperatures narrowed with increasing silicon content.

Figure 3 indicates that increasing amounts of manganese cause the upper critical temperature to drop. Table I indicates the austenitizing temperatures selected for subsequent work along with the corresponding silicon and manganese contents.

Hardenability Is Important, Too

Since ductile iron can be heat treated to high strengths, its hardenability characteristics are important. In particular, heat treaters must know the depth to which full hardness can be achieved in quenching. To determine these characteristics, end-quench tests were performed on bars of each composition austenitized at 1550 and 1700° F. (temperatures commonly used in current practice).

In examining Fig. 4, which illustrates hardenability curves for the series in which the silicon content was varied, a number of factors are immediately apparent. First, since much greater hardenabilities are achieved by austenitizing at 1700° F., it is evident that 1550° F. is too low a temperature for austenitizing irons of these silicon and manganese contents. Second, silicon appears to influence hardenability slightly, at least in the higher ranges. Third, the curve for the bar containing 4.12% Si, quenched from 1700° F., shows two plateaus at which the hardness readings are essentially the same for short distances along the bars. These hardness plateaus suggest the presence of intermediate microconstituents. The most obvious structure would be bainite, with the

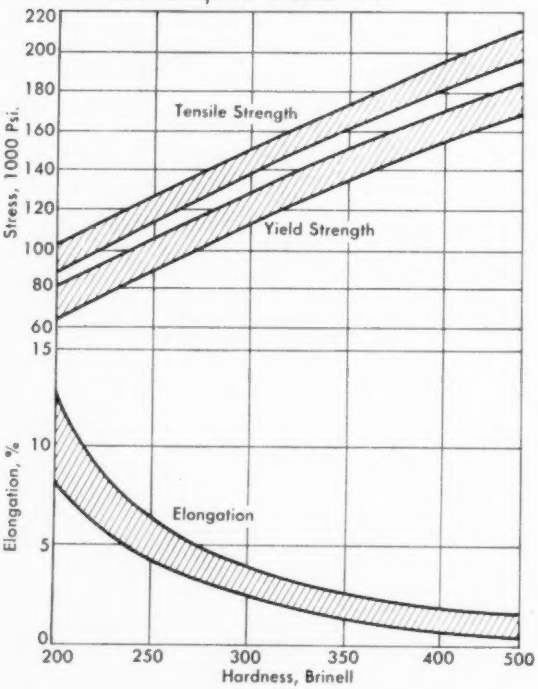
Specifications and Properties of Nodular (Ductile) Iron Castings

Specifications	Class	Minimum Mechanical Properties: Tensile Strength, Psi.	Yield Strength, Psi.	Elongation in 2 In., %	Heat Treatment	Typical Applications
A.S.T.M. A 339-55	80-60-03	80,000	60,000	3	As cast	Heavy-duty machinery, gears, disks, rolls for wear and strength
	60-45-10	60,000	45,000	10	Usually annealed	Pressurized parts, valve and pump bodies, compressor heads, shock-resisting parts
A.S.T.M. A 395-55 T	60-45-15	60,000	45,000	15	Ferritized by annealing, 3.0 total C (min.), 2.75 Si (max.), 0.08 P (max.)	Valves and fittings for steam and chemical plant equipment, steam driers, other pressurized parts
MIL-I-17166A (Ships)	60-40-15	60,000	40,000	15	Ferritized by annealing to Bhn. 190 (max.), 3.0 total C (min.), 2.50 Si (max.), 0.08 P (max.), 4.5 carbon equivalent (max.)	Motor frames and ends, engine blocks, heads, compressors, valves, clamps
A.S.T.M. A 396-55 T	120-90-02	120,000	90,000	2	Quenched and tempered	Pinions, gears, cams, guides, track rollers
	100-70-03	100,000	70,000	3		
MIL-I-11466 (Ordnance)	1	120,000	90,000	2	Quenched and tempered	Military equipment
	2	100,000	75,000	4		
	3	85,000	60,000	6		
	4	80,000	60,000	3	Generally as cast	
	5	60,000	45,000	10	Ferritized by annealing	
	6	60,000	40,000	18		

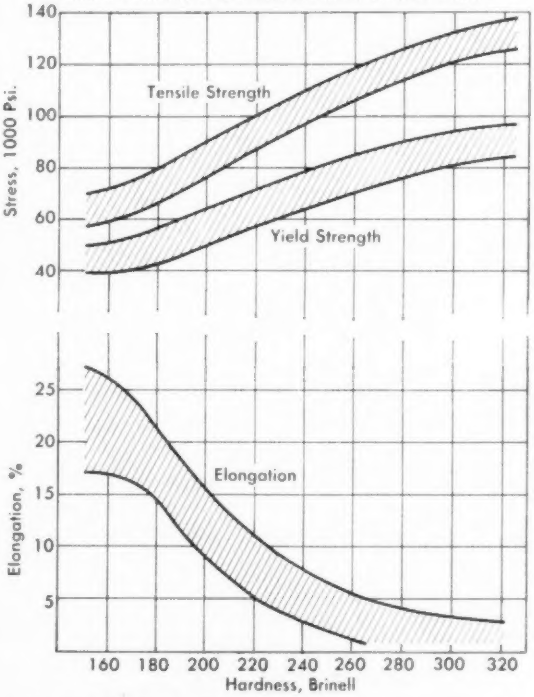
Other than the high-alloy grades, the various types of nodular iron all have essentially the same chemical composition; they differ in the microstructure which surrounds the graphite. These different structures can be produced by heat treatment. A full anneal produces a ferritic matrix and high ductility (Grade 60-45-10), normalizing provides a pearlitic structure with good machinability as well as strength (Grade 100-70-03) and quenching and tempering gives a high yield strength while maintaining machinability (Grade 120-90-02).

In actual practice, however, the composition may be varied to make it easier to obtain a desired structure. For example, carbide-stabilizing elements are generally held to a minimum in castings to be annealed, and in castings of medium and large size, the 80-60-03 grade can often be obtained without heat treatment by proper adjustment in the composition.

Typical Properties of Quenched and Tempered Nodular Iron

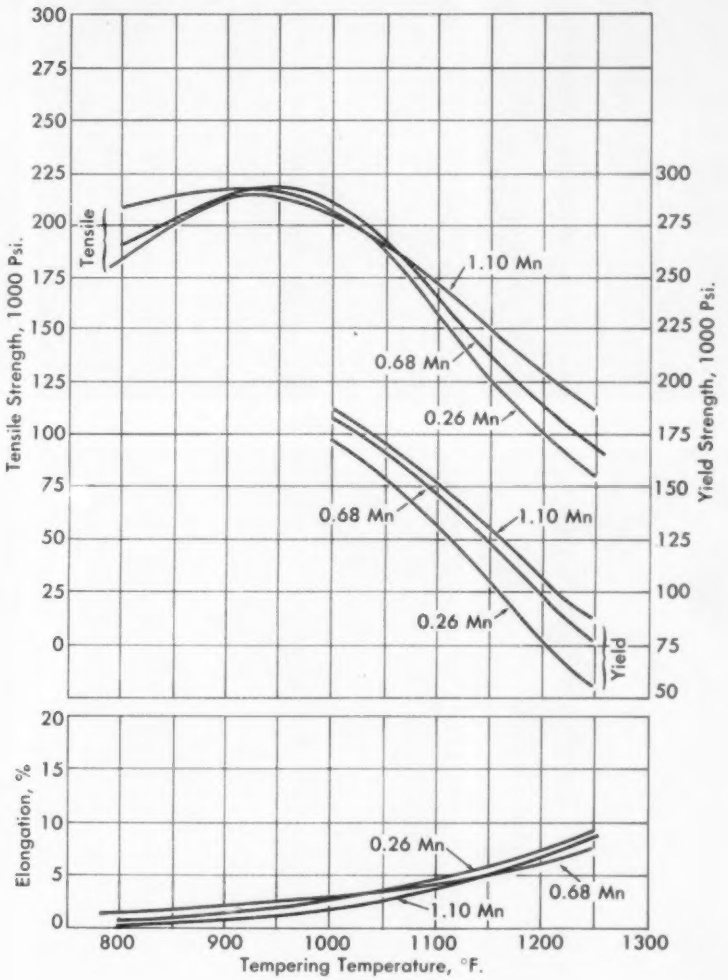


Typical Properties of As-cast, Annealed, or Normalized Pearlitic or Ferritic Nodular Iron or Both



Courtesy Gray Iron Castings Handbook, Gray Iron Founders' Society, Cleveland.

Fig. 9 – Effect of Varying Manganese Contents on Tensile Properties of Experimental Irons. At lower tempering temperatures, manganese has no effect, but above 1100° F. the added manganese raises strength slightly. This effect is the reverse of that of silicon (shown in Fig. 8). Carbon, 3.75%; silicon, 2.45%



first plateau representing a section of upper bainite, and the second, lower bainite.

Figure 5 shows the effect of manganese on hardenability of ductile iron. As with the material with varying silicon contents, 1550° F. is also inadequate as an austenitizing temperature. The curves derived from specimens austenitized at 1700° F. show the striking influence of manganese in increasing hardenability.

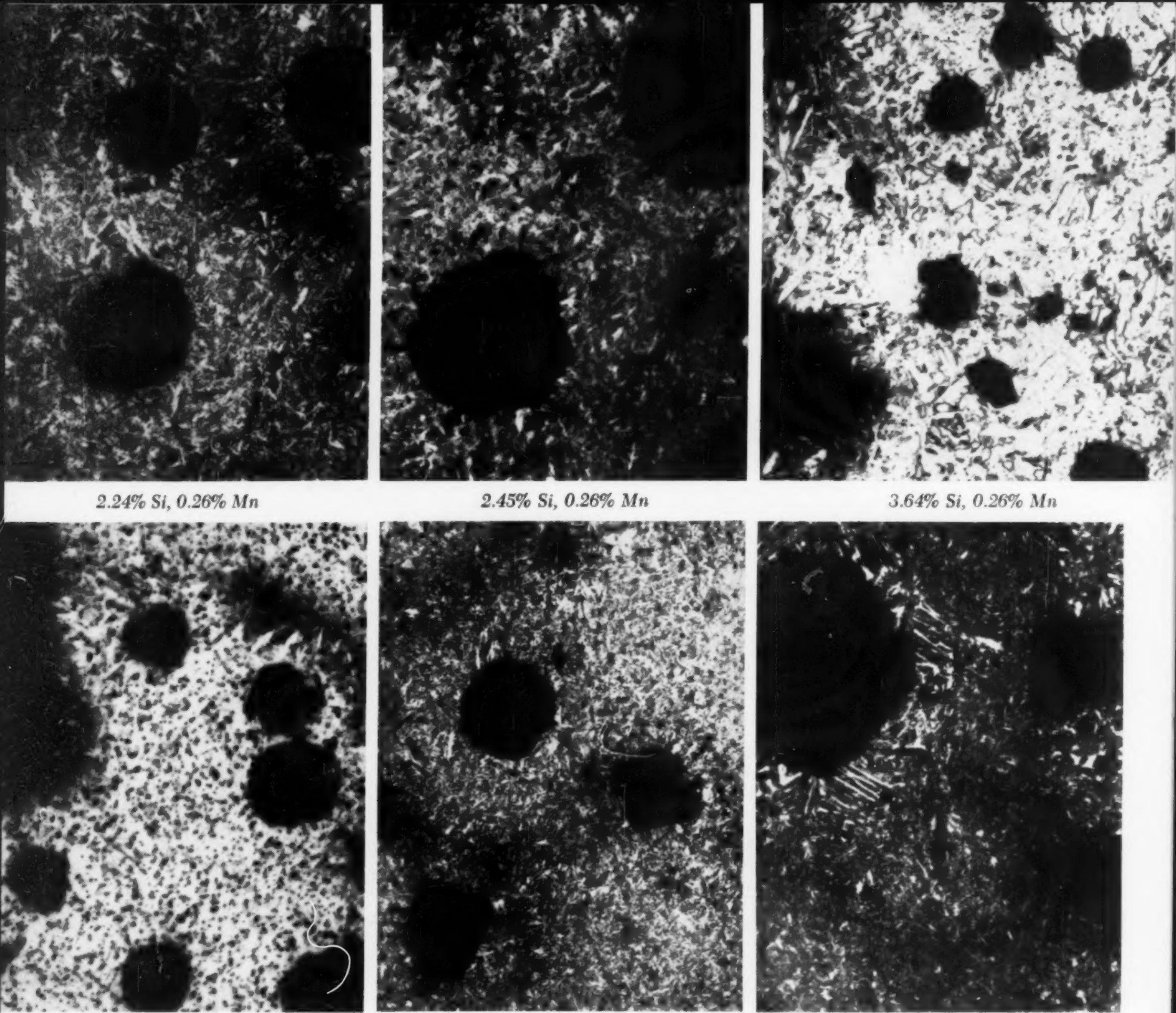
Temperability, Another Factor of Interest

The tempering response of martensitic structure is often important from two standpoints. Heat treaters must know both the absolute hardnesses attainable at various tempering temperatures and the rate at which these hardnesses change with variations in tempering temperature. Both factors are important for establishing heat treating procedures.

Figures 6 and 7 show how the experimental irons responded to tempering. Generally, the high-silicon irons softened rapidly on tempering in the 1000 to 1200° F. range, and the addition of manganese made the tempering reaction more sluggish. Moreover, a comparison of the two figures shows that manganese content is a more potent factor in changing response to tempering than silicon.

Tensile Properties Must Be Considered

Since ductile iron is primarily a structural engineering material, a thorough knowledge and comprehensive understanding of its tensile properties is very important. This is especially true because the properties can be regulated by controlling both composition and heat treatment. Figures 8 and 9 show tensile properties of the irons studied in this investigation as a



2.24% Si, 0.26% Mn — *2.45% Si, 0.26% Mn* — *3.64% Si, 0.26% Mn*

4.12% Si, 0.26% Mn — *2.36% Si, 0.68% Mn* — *2.62 Si, 1.10% Mn*

Fig. 10 – Microstructures of Representative Experimental Irons After Quenching and Tempering at 1200° F. Note that the irons with lower silicon (2.24 and 2.45%) are more completely martensitic than those with 3.64 and 4.12% Si. Also, the effect of higher manganese contents is evident; the 0.68% Mn iron has only a few small needles of free ferrite while the 1.10% Mn is completely martensitic. Etchant: 3% Nital; 500 ×

function of the tempering temperatures normally used in conventional heat treating. As is customary in most ferrous materials, ductilities rose and tensile strengths fell with increases in the tempering temperature. It is significant to note that the highest tensile strength achieved was 265,000 psi. (obtained with the iron containing 4.12% Si). For the medium-silicon irons, the highest strength was about 220,000 psi. for the iron containing 1.10% Mn. Since for all practical purposes, the irons tempered at less than 800° F. are too hard for ready machinability and have poor shock resistance, attention should be focused on the values produced by higher tempering temperatures. As is evident from examining Fig. 8, silicon raises the tensile strength particularly at the lower tempering temperatures (up to 1050° F.). Above this temperature the effect of extra silicon drops until at 1200° F., it is completely gone. Manganese has a reverse effect on tensile strength as Fig. 9 shows. At the lower tempering temperatures, increased manganese contents had no effect on the tensile strength, *(Continued on p. 142)*

Cast Chromium Nickel Stainless Steels for Superior Resistance to Stress Corrosion

Stress corrosion of stainless steels has become an increasingly important problem in the chemical process industries, as well as in power-generating systems utilizing steam and high-temperature water. Higher strength and improved resistance to stress corrosion can be obtained from stainless alloy castings through control of the amount of ferrite in the material. (R1d; SS)

*By M. G. FONTANA, F. H. BECK and J. W. FLOWERS**

During work leading to the development of Type CD-4MCu, a new high-strength stainless cast alloy with excellent corrosion resistance, it was observed that alloys containing high ferrite showed very good resistance to stress-corrosion cracking. This observation led to an extensive study of the effect of ferrite on mechanical properties and resistance to stress corrosion in 18-8 stainless steel and in other alloys.

Special Stress-Corrosion Test

The apparatus used in determining resistance to stress corrosion is described in detail elsewhere.† Figure 1 is an assembled and exploded view and Fig. 2 is a schematic drawing of the autoclave used in the tests. The walls of the autoclave are heated electrically but the top is not heated and is not insulated. Vapors condense on the top and drip on to the test specimen, which is stressed in the device shown in Fig. 3.

Specimens are also immersed in the solution, but here higher stresses and longer times are required for the onset of cracking. If a Teflon umbrella is placed over the specimen, as shown in Fig. 2, cracking does not occur. Only the top or vapor position with no umbrella was used for the studies reported here. Results from this test, known as the vapor condensation test for stress corrosion, correlate well with actual plant experience involving chloride-containing waters and other solutions.‡

*Mr. Fontana is professor and chairman, Department of Metallurgical Engineering, Ohio State University, Columbus, Ohio. Dr. Beck is research professor and Mr. Flowers is research fellow at the University's Engineering Experiment Station. This research was sponsored by the Alloy Casting Institute.

†"Mechanism of Stress Corrosion of Austenitic Stainless Steels in Chloride Waters", by R. W. Staehle, F. H. Beck and M. G. Fontana, *Corrosion*, Vol. 15, July 1959, p. 51-59.

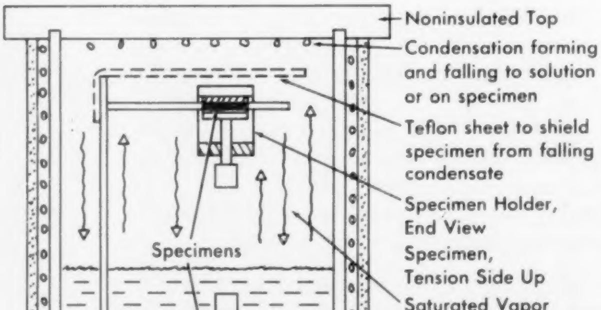
‡"Some Unusual Corrosion Problems in the Chemical Process Industries", by M. G. Fontana, *Proceedings* of the First International Conference on Metallic Corrosion, London, April 1961.

Fig. 1 – Assembled and Exploded Views of Autoclaves Used in Stress-Corrosion Tests

Data were obtained under the following conditions: distilled water containing 875 ppm. of sodium chloride is heated to 400° F.; specimens are exposed for 8 hr. Many of the results obtained are summarized in Fig. 4; actual data for one alloy, CF-3, are presented below:

Ferrite	Applied Stress 1000 Psi.	Cracked?
3.6%	29 (90% of yield)	Yes
3.6	10	Yes
3.6	7 (2 tests)	Yes
3.6	5 (2 tests)	No

Fig. 2 – Schematic Diagram of Autoclave in Operation



Thirteen Years of Continuous Exposure to One of the Most Corrosive Environments in the Chemical Industry – a Solution of Calcium and Magnesium Chlorides at 220° F. With Solid NaCl in Suspension – Have Had No Effect on Two Large Pumps Made of Type CF-8M Alloy Castings. The alloy contains significant amounts of ferrite, corroborating research findings that ferrite increases resistance to stress-corrosion cracking. Pump parts made of other materials fail in this environment in from 15 months to five years. (Courtesy Westvaco Chlor - Alkali Div., Food Machinery & Chemical Corp.)

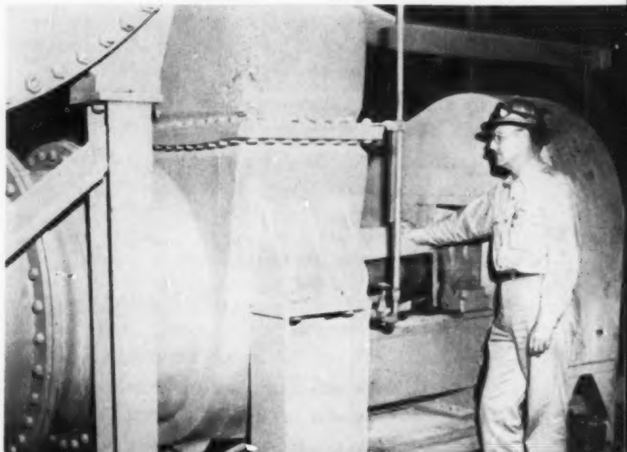


Table I – Chemical Composition, Ferrite Content and Mechanical Properties of Alloys Tested

Alloy Designation	Ferrite, %	Composition, %							Room-Temperature Mechanical Properties‡				
		C	Mn	Si	Cr	Ni	Mo	N	Tensile Strength, Psi.	Yield Strength, Psi.	Elongation, %	Reduction in Area, %	Hardness, Bhn.
A.C.I. Type*													
CF-3	0	0.02	0.78	1.20	16.97	13.35	—	0.030	61,200	25,400	62.5	74	116
CF-3	3.6	0.02	0.83	1.29	19.28	10.07	—	0.075	71,800	31,800	72.5	68	133
CF-3	36.6	0.02	0.83	1.50	21.81	7.68	—	0.056	89,100	51,000	47.5	67	164
CF-8	0	0.08	0.74	1.22	18.08	12.20	—	0.050	66,900	29,900	60.0	65	127
CF-8	5.0	0.07	0.80	1.25	19.99	9.38	—	0.062	77,600	36,300	59.5	68	158
CF-8	15.8	0.08	0.78	1.28	21.37	8.08	—	0.077	86,800	47,100	52.0	64	156
CF-8M	0	0.08	0.85	1.12	16.72	15.02	2.51	0.042	66,950	30,000	56.5	65	129
CF-8M	2.0	0.07	0.61	1.30	18.99	11.36	2.68	0.074	80,200	42,000	60.0	58	160
CF-8M	15.0	0.07	0.79	1.39	20.17	9.55	2.40	0.064	87,800	48,400	45.0	64	164
CD-4MCu (S.A.)	65.0	0.025	0.89	0.90	25.03	5.32	2.08	3.15 (Cu)	107,500	97,900	16.8	44	228
CD-4MCu (Aged)	—	—	—	—	—	—	—	—	138,800	100,700	9.4	10	306
CE-30	28.2	0.25	0.54	1.80	28.16	9.64	—	—	100,200	62,500	18.8	17.8	190
CG-8M	16.5	0.056	1.12	1.06	20.17	10.40	3.52	—	86,750	44,550	41.5	59	156
CN-7M	0	0.04	0.70	0.88	20.22	29.78	2.75	3.50 (Cu)	65,000	28,300	45	69	140
Inconel (Cb)	0	0.052	0.79	1.28	14.2	73.20	—	1.89 (Cb)	76,200	28,600	41	39	132
A.I.S.I. Type†													
304	0	0.06	1.42	0.38	18.24	8.84	—	—	85,000	35,000	55	65	150
316	0	0.08	1.47	0.20	17.88	12.02	2.20	—	85,000	35,000	55	70	150

*Except for alloy CD-4MCu, all cast specimens were water quenched from 2050° F. Alloy CD-4MCu was solution annealed from 2050° F. and aged 3 hr. at 900° F.

†Wrought alloys water quenched from 2050° F.

‡Nominal mechanical properties listed for Type 304 and 316; for cast alloys actual test results are shown.

These data are plotted as a point (3.6% ferrite, 6000 psi.) in Fig. 4.

Materials Studied – Three cast 18-8 stainless alloys with zero, intermediate, and high ferrite contents – CF-3, CF-8 and CF-8M – were tested. The wrought counterparts of CF-8 and CF-8M, Type 304 and 316, were also included. (Wrought alloys are made intentionally with zero ferrite to facilitate hot working and thus the advantages of ferrite cannot be obtained.) Other cast alloys tested were CD-4MCu, CE-30, CG-8M, CN-7M and Inconel containing 1.9% Cb. Table I lists the ferrite content, chemical composition, heat treatment, and mechanical properties of these alloys.

Effect of Ferrite

The effects of ferrite in CF-3, CF-8 and CF-8M are shown in Fig. 4. Note the relatively poor resistance to stress corrosion for the completely austenitic (0% ferrite; nonmagnetic) alloys including Type 304 and 316. Resistance to stress corrosion increases rapidly as ferrite content increases; there is a 15-fold increase in resistance for the low-carbon CF-3 alloy.

Substantial increases in the strength of these alloys with increasing ferrite are clearly shown in Table I. The two-phase structure of the

Fig. 3 – Specimen Support Rack Showing Mechanism for Applying Stress

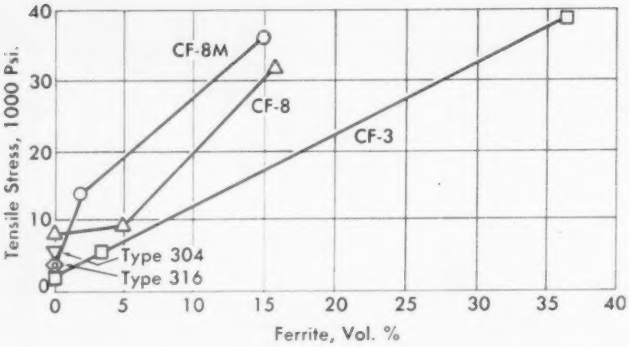


Fig. 4 – Effect of Ferrite on Stress Required to Induce Stress-Corrosion Cracking in Several Cast Stainless Alloys. Type 304 and 316 with zero ferrite also plotted. Specimens exposed 8-hr. in condensate from 875 ppm. chloride water at 400° F.

castings is a definite advantage here because the producer has very little difficulty in rolling austenitic steels with high ferrite contents, and higher mechanical properties permit designing to higher strength levels.

Other Alloys Also Important

CE-30, with higher alloy content, did not crack in tests involving applied stresses as high as 70,000 psi. The Inconel alloy exhibited similar behavior at stresses up to 50,000 psi. CN-7M alloy cracked at 31,500 psi. These stresses are all above the yield point of the alloys and therefore are not the true stresses developed during the test, but were the stresses applied as testing was initiated. Alloy CG-8M cracked at approximately 42,500 psi.

Alloy CD-4MCu cracked at about 55,000 psi. in the solution-annealed condition, and at about 65,000 psi. in the aged condition. Here is a case of a low-nickel (5%) alloy showing good resistance to stress corrosion in a chloride environment. This behavior has been confirmed by Navy tests and as a result parts made of CD-4MCu alloy are in a nuclear submarine. This alloy also shows good resistance to corrosion fatigue – a type of stress corrosion involving alternating cycles of applied stress.

Of all the alloys discussed here, CN-7M (often called Alloy 20) and CD-4MCu alloys have the best over-all resistance to corrosion in relatively severe environments, such as in sulfuric acid.

The Microstructures

Typical stress-corrosion cracks found in Type 304 stainless steel are shown in Fig. 5. Similar transgranular cracks occur in fully austenitic castings of essentially the same composition (CF-8). Figure 6 shows the end of a crack in CF-8, containing 15.8 vol. % ferrite, which was stressed at 33,000 psi. Note that the crack did not pass through the ferrite area but propagated in the austenite beneath the ferrite and emerged on the other side. This helps explain the beneficial effect of ferrite in cast austenite stainless steels – namely, that the ferrite provides a "keying action" and blocks direct propagation of cracks.

Fig. 5 – Transgranular Cracks in Type 304. Stress applied during stress-corrosion test was 7500 psi. 90×

Fig. 6 – Transgranular Crack in CF-8 Alloy Containing 15.8% ferrite. Applied stress, 33,000 psi. Ferrite area has inhibited crack propagation. 375×

Materials Research in Europe

My Mission in Europe

By SAMUEL L. HOYT
Metallurgical Consultant
Berkeley, Calif.

". . . as staff representative of the Research and Engineering Div. of our Department of Defense, I found a strong interest in current problems and a common bond between scientific and technical personnel, both with us in the United States and with each other."

IN MAY 1959 I EMBARKED on the S.S. *America* for Europe and in September 1960 I disembarked at Brooklyn from the transport *Upshur*. In the intervening months, as staff representative of the Research and Engineering Div. of our Department of Defense on a special mission to the NATO countries, I visited many leading people working in research and technology in Europe to compare notes and swap information.

Since I was familiar with Germany and able to speak the language – and the work underway there was important, as well – I was given "logistical and administrative support" by the Army and a desk at its European Research Office in Frankfurt am Main. However, Frankfurt was only my headquarters. I also visited Sweden, Belgium, England, France, Switzerland, Austria and Spain. Since Western Europe is very active in both research and technology, it is wise for us to maintain close liaison with our counterparts over there.

Research Agencies Abroad

I have mentioned the Army's ERO in Germany. Our Navy has a similar office in England at London and our Air Force has one in Brussels, Belgium. A few words about these three research agencies may be in order. Any qualified investigator who knows of the support we give to research in Europe can request funds for a program on which he wishes to work by submitting a proposal to one of these offices. The proposal is then sent back to the United States to the appropriate agency for review. If accepted, the agency usually provides the funds and monitors the work. Word is also passed on to the two other offices, notifying them of the receipt of a proposal and the action taken. In addition, Triservice Coordination Meetings are held at three-month intervals to discuss operations and other pertinent points.

Fortunately, the powers-that-be understood research well enough to allow liberal terms in the contracts. The investigator does what he wishes to do under conditions which are not at all onerous. He also has publication rights and can patent his findings. Every one is happy and our literature is enriched by the publications which ensue. Of course, these are basic and unclassified investigations. Most of the contracts which we support are in fields such as chemistry, physics, electronics, biological and medical sciences and astronautics.

It will surprise no one to learn that England heads the countries in which we support research. England is not only a leader in science but, in that country, there is no language barrier – in spite of the many quips to the contrary. An American soon learns that an elevator

is a "lift" and that he "ques up" and "books" passage on train or plane. Moreover, the English have learned how we handle their language.

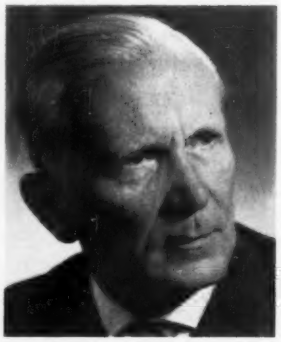
However, it may come as a surprise to some that Germany is second in number and dollar value of research contracts. France, of course, is not far behind, and all three services have strong programs there. To a lesser extent we also support research in other countries of Western Europe, and there is a small effort in a few additional countries which have the need and the desire to develop a scientific potential.

Georges Blanc, Scientific Director of the Centre Technique des Industries de la Fonderie in France

Materials Research Efforts

So much for the broad picture. When we turn to materials, and particularly to metallurgy, we find a great disparity between the present significance of materials and the degree of our support to European investigators. Germany is the outstanding example of this neglect. In spite of its very substantial potential in brains, experience and facilities for research, our cooperation with their investigators in this field is exceedingly small.

The picture in England is similar to that in this country, although there are some modifications which come from their more basic approach, in general, to the execution of programs. Their problems are similar to ours and there is great similarity in objectives and techniques. At the British Welding Research Assoc., the British Iron and Steel Research Assoc., and several other laboratories on steel research, I noticed the emphasis put on analyzing a problem and the systematic attack on its solution. This approach not only establishes a good program for the work but also makes possible a sounder judgment of the results, whether they are positive or negative – a point that is often overlooked.



Dr. Werner Köster, Director of the Max Planck Institut für Metallforschung, in Stuttgart, West Germany

Studies of Brittle Fracture

Weldability and brittle fracture offered a good starting point, and it was a pleasure to check on some of the English work in this area. My first visit was to Dr. C. F. Tipper at Cambridge to go over her brittle fracture studies. I had known her earlier as Constance Elam, part of the Carpenter and Elam team working on single crystals. (Incidentally, she is the only metallurgist of her sex to gain international recognition under both her maiden name and married name.) Her work on deformation and fracture of single crystals gives an excellent introduction to mechanics of the notch effect.

Dr. Tipper has an excellent collection of her own test samples and of brittle service failures which she is pleased to discuss with interested visitors. Marked emphasis there, as elsewhere in England, is on fracture appearance which, as used, is a controversial point. Which reminds me that one day, when looking across the Rhein at the Lorelei, it occurred to me that fracture appearances can be a good guide provided you don't get wrecked on it. Tests for susceptibility to brittle fracture deal with specimens and test procedure, and criteria to use for the transition temperature. Each experimenter has his own pet methods which satisfy him (but not many others). I found no violent disagreement with the idea of using service failures as guides, although not many do so. On a macroscale the brittle service failure shows no evidence of plastic deformation which

Dr. Willy Oelsen, Director of the Max Planck Institut für Eisenforschung, Düsseldorf, West Germany

Dr. R. Weck (Left), Director, and A. A. Wells, British Welding Research Assoc., Cambridge, England, Examine a Brittle Fracture of a 3-In. Plate With Welded-In Nozzle

Dr. (h.c.) Angelica Schrader, Top Flight Microscopist, Has Just Retired From the Max Planck Institut für Eisenforschung

preceded fracture, and the fracture is the brittle type. Therefore, it must be correct to use this behavior to define the transition temperature. Furthermore, according to this criterion, the transition temperature is the highest temperature at which the prevailing conditions (stress system or notch effect and the strain rate) produce this behavior or brittle fracture.

I saw some evidence of a swing in this direction in recent English work which accepts the highest temperature of true brittle fracture as the valid transition temperature. That is the Match Point which I have advocated as the one point on the transition curve which has precise significance and which gives a fracture that is the same as the brittle fracture of service.

At BWRA I discussed weldability with Dr. H. F. Tremlett and his basic approach to a project we are sponsoring on the weldability of hardenable steels. The program consists of determining transformation on continuous cooling at different rates for a graded series of steels. Special attention will be paid to prior structure, cooling rate, retained austenite, and to preparing the test materials. What – no welding? Welding tests will come later after the ground rules are established. The approach of the BWRA is to eliminate all variables except the one under investigation, the desirability of which is equaled only by the difficulty of accomplishing it.

Bristol-Aerojet is the only facility which is fabricating missile casings of super high-strength steels. The properties under uniaxial and multiaxial stress and weldability are critically important as are fabrication techniques and inspection. Discussions with F. J. Wilkinson and C. L. M. Cottrell showed that their experience coincides with my own on Polaris engine bodies. We also agreed on the probable reasons these steels have fallen short of their full potential and on what is needed to attain it in production. Dr. Cottrell has a weldability test which agrees nicely with their shop experience. However, other investigators have tried it, too, and they were quick to point out shortcomings which they have found – and so it goes.

Other English work which I was able to investigate was of the same high quality, such as work in electron microscopy by J. Nutting at Cambridge and R. W. K. Honeycombe at Shef-

field, on graphite at Hawker-Siddley, on steel research at BISRA and Mond Nickel, and in high-temperature research at Fulmer.

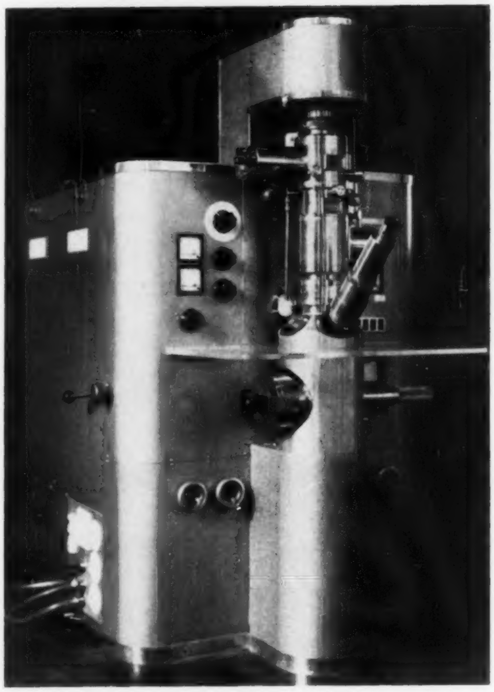
Visits to French Laboratories

Many years ago while a student in Germany, I learned that the French are exceptional in getting the clue to a fruitful idea. By a motion of his hand, my German professor indicated that they simply pluck it out of the air. That intuition is still preserved in various French laboratories that I visited. Although any general statement can be controverted by citing specific cases, I found that, what we are apt to do the hard way, the English handle by the guidance of serious analysis and the French by intuition. The latter is the easy way – if you can manage it.

Grain boundary research is still actively pursued in Europe – most is basic though some is applied. Prof. Honeycombe shows the chromium impoverishment at grain boundaries of sensitive 18-8 such as Ed Bain postulated years ago. One of the finest demonstrations I saw was at Institut de Recherches de la Sidérurgie, the large research institute of the French steel industry. With the electron probe microanalyzer they show a 25-fold chromium enrichment at grain boundaries of plain carbon steels though they cannot duplicate with some of the harmful impurity elements of low atomic weight.

IRSID is very active in studies of the micromechanism of brittle fracture, trying to understand the variables, temperature, strain rate and triaxiality. These they refer to as being "equivalent"! The first two determine the properties, though not as equivalents would, while the latter determines the stress field. Obviously, they have the wrong approach here, but the same criticism cannot be leveled at their experimental work.

At the famous Sorbonne Prof. A. Michel studies the carbides of steel, including iron carbide and the effects of manganese, nitrogen, cobalt, nickel, sulfur and boron. Prof. J. Benard also specializes and his interest is the reactions or effects of gases on heated metals. Both have excellent technique. At the École Polytechnique, the top technical institute in France with very high admittance requirements, Prof. Jacqué is oriented in petrochemical work but he also studies pertinent reactions with metals at elevated temperatures.



New Electron Emission Microscope Used by Dr. H. Düker at the Max Planck Institut für Metallforschung's "Special Metals Institute"

I also visited my friend Georges Blanc, director of the big government institute for foundry research. He tackles problems from advanced research to the development of new practice. Since my last visit, he has added scientific equipment to study problems in more fundamental fashion.

Facilities for Specialized Research

A new feature of research in both England and France is the small specialized institute at which university professors spend part of their time. Their specialized services are thus made available to others on a contract basis. Examples are Nutting in electron microscopy and Jacqué in chemical engineering.

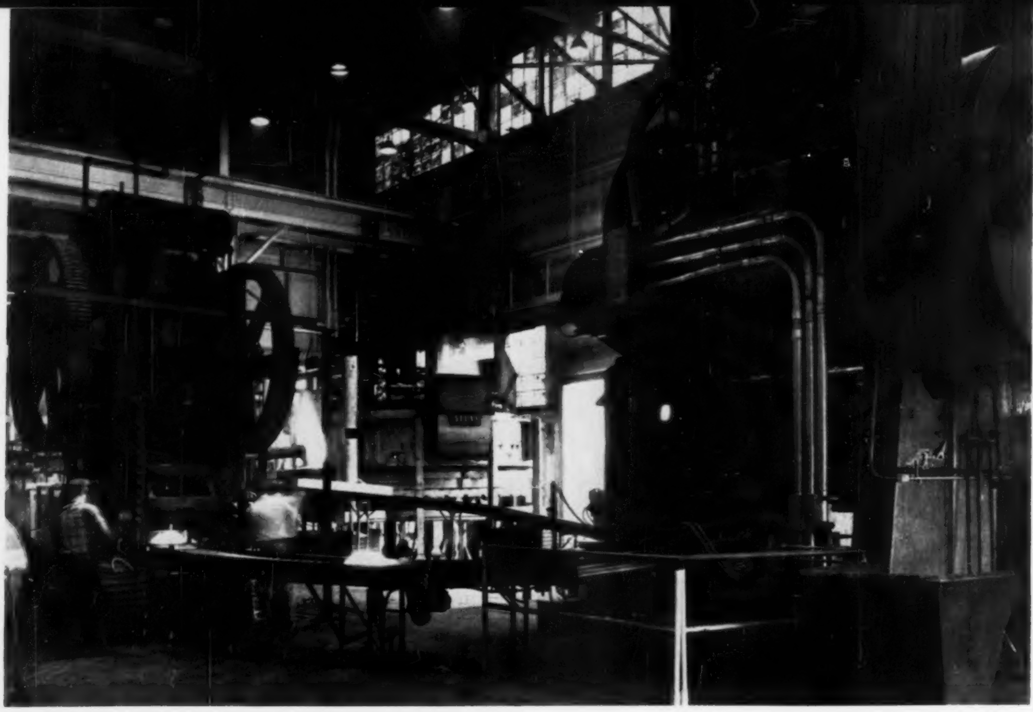
As mentioned before, Germany was given special attention, a task that was greatly simplified and expedited by my knowledge of German. One of my first contacts was Prof. Werner Köster, director of the Max Planck Institut für Metallforschung in Stuttgart. I had become well acquainted with him in 1945 as metallurgist with *(Continued on p. 120)*

Gamma-Prime Precipitate in a Nickel-Base Alloy

Metallographic Exhibit

Grand Prize

THIS ELECTRON PHOTOMICROGRAPH, one of a pair entered in the 16th A.S.M. Metallographic Exhibit by J. F. Radavich (Purdue University) and W. H. Couts, Jr. (General Electric Co.), won the Francis E. Lucas Award of $500 during the recent 43rd National Metal Congress and Exposition in Detroit. The large islands of gamma prime in the micrograph, formed in 100 hr. at 1900° F., show a second carbide phase when treated an additional 16 hr. at 1400° F. The gamma-gamma prime interface shows a hexagonal structure. The nickel-base alloy contained 4.5% Al and 3.5% Ti and the structure is typical of new age-hardening alloys such as René 41 and Udimet 700. Original mag. 18,500 ×, reduced for printing to 12,300 ×.



Ajax 6000-Ton Mechanical Forging Press (Far Right) Transforms 6-In. Square Steel Billets to Complete Gear Blanks in Three Strokes. Rotary hearth furnace (center background) supplies heated billets to the press via conveyor. Press at left trims forged gear blanks

Automatic Forging of Steel Gears

*By JOHN G. WILSON**

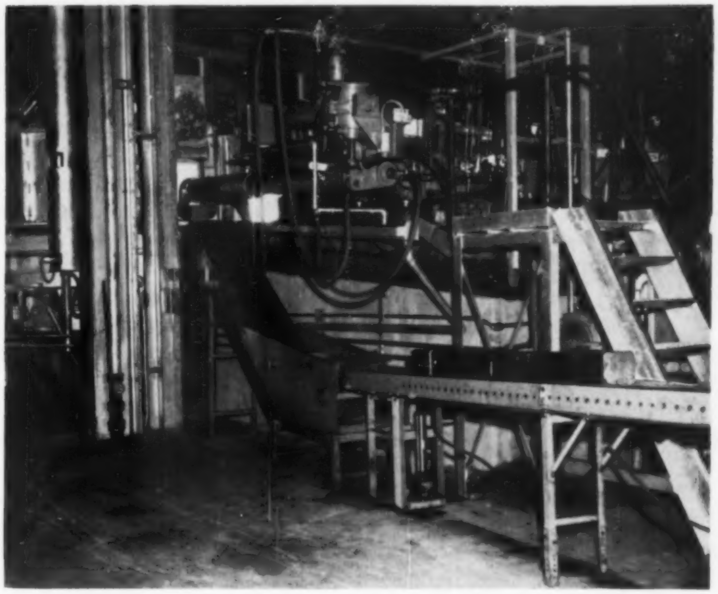
An automatic rotary hearth furnace teamed with a 6000-ton mechanical press provides faster, controlled heating for improved forgeability, lower costs, and less scaling. The automatic setup also produces more accurate, higher-quality steel forgings. (F22, T7a, W22p; AY)

IT REQUIRES ONLY 31 MIN. to transform a cold billet to a forged-and-trimmed gear blank on an automatic press line at Eaton Mfg. Co.'s Marion Forge Div. A 6000-ton Ajax mechanical press, with an automatic manipulator which moves work through a three-stage die, operates at 35 strokes per minute to produce pinion forgings and transmission gears ranging in size from 13 in. outside diameter (45 lb.) to 18½ in. outside diameter (130 lb.).

Operating in conjunction with the press is a 25-ft. diameter rotary hearth furnace that

*Plant Engineer, Marion Forge Div., Eaton Mfg. Co., Marion, Ohio.

Fig. 1 – Cold Billets on Storage Conveyor Wait While Billet Is Placed on Furnace Hearth



charges and unloads ingot. It heats round-cornered steel billets (4 to 7 in. square, in lengths ranging from 5½ to 12⅝ in.) to forging temperature, and production is synchronized to keep pace with the maximum forging capacity of the press. The furnace replaces several slot-type, manually operated forging furnaces.

Automatic conveying equipment transports A.I.S.I. 8620 and 4718 steel billets from a cutting station to the furnace, directly from the furnace discharge to the press, and then to the trimmer. Three men can operate the entire forging line.

Automatic Rotary Furnace

The direct-heating radiant furnace, made by Selas Corp. of America, contains a power-driven hearth which conveys the work in a clockwise direction from the charge door through controlled heating zones to the discharge door. Zone one, equipped with high-low temperature control, heats the work at maximum rate, and zone two completes the heating of the billet to the desired temperature. Zone three is a "soaking" zone in which the billet attains uniform temperature. Automatic indexing of the hearth is controlled by a synchronous electric timer whose interval setting is based on the required over-all heating time.

Three rows of nozzle-mixing radiant burners, located in the roof and spaced at strategic intervals only inches from the work, beam heat at high thermal gradient directly to the billets with the result that the average billet is heated to 2300° F. in only 30 min.

The desired fuel-air ratio in all zones is maintained automatically by a Hagan ratio control system which regulates the quantity of combustion air delivered from a turbo-blower to the burners in direct proportion to the fuel demand as measured at gas flow orifices in each zone. The furnace atmosphere is usually kept slightly reducing for all forging jobs to minimize scale formation.

Operation of the Furnace

Automatic operation begins with the conveying of cold billets, at controlled intervals, into position for loading into the furnace (see Fig. 1).

Billets are positioned in two concentric circles (Fig. 2) on the furnace hearth to achieve higher production rates. Steps on the hearth incline the billets so that each one contacts the hearth at only two points. This has the dual advantage of decreasing heating time (by taking utmost advantage of convection currents moving under and around the billets) and minimizing total area in direct contact with the cooler hearth.

An unusual feature of the installation is the manipulator shown in Fig. 3, which places cold billets one at a time on the hearth and simulta-

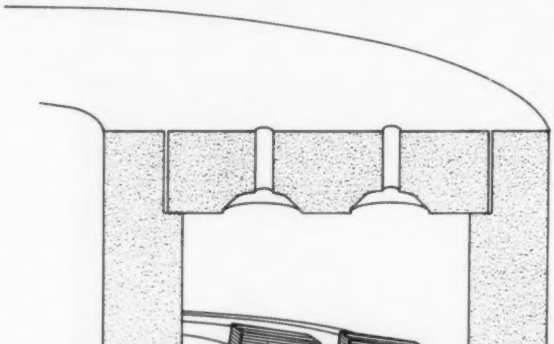


Fig. 2 – Placement of Billets on Hearth in Two Concentric Circles. This loading takes advantage of convection currents around work to supplement direct radiant heat from burners in roof

neously removes individual heated pieces. It is essentially a track-mounted carriage whose forward and retracting motions are hydraulically propelled. On this carriage are two independent water-cooled alloy peels, one for charging and the other for unloading. Space under the peels is open for charging and discharging of billets without interference with any of the conveying equipment. A range of billet lengths can be accommodated with only a simple adjustment of a limit switch on the manipulator feeding conveyor. The entire mechanism is floor mounted, entirely open on the sides, free of all overhead frame members, and readily accessible for maintenance or adjustment.

Since there are two circles (or rows) of billets on the hearth, charging and unloading is a unique, two-phase operation. In phase one, the charging peels pick up a cold billet from the storage conveyor and, as the carriage moves forward, reach into the furnace charge door, placing the cold billet on the inner row of the hearth. Simultaneously the unloader peels, reaching into the unloading door, grasp a hot billet from the outer row of the hearth. The carriage then withdraws, causing the unloader peel to deposit the heated billet, in motion, onto the press feed conveyor (Fig. 4).

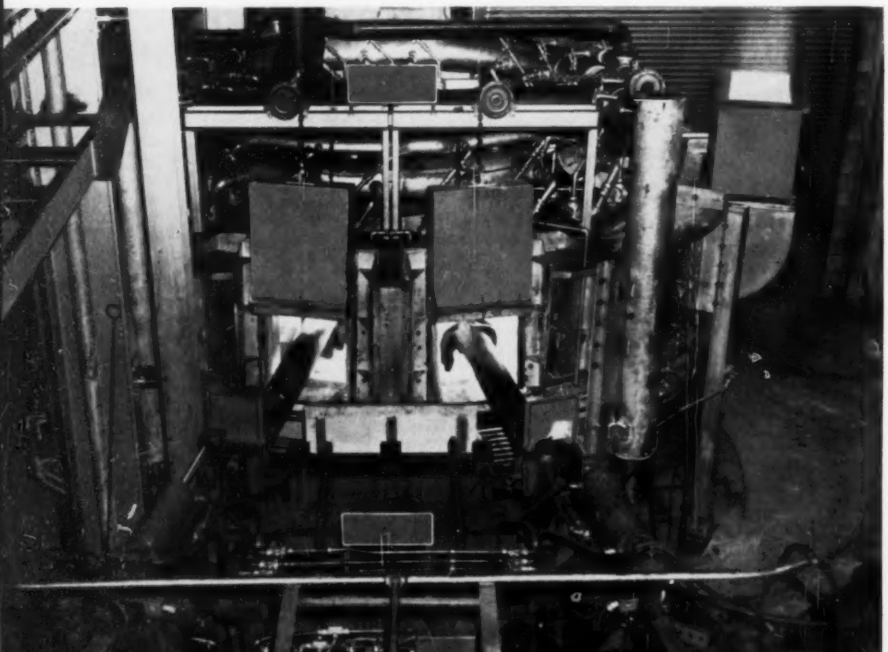


Fig. 3 – While a Cold Billet Is Placed on Inner Row of Furnace Hearth (Left), a Heated Billet Is Removed From Outer Row (Right)

In phase two, the charging peels, restored to position above the cold-billet storage conveyor, grasp a waiting billet. The carriage again moves forward, the charging peels reaching into the furnace and depositing the cold billet on the outer row of the hearth. At the same time, unloader peels, reaching into the furnace unloading door, grasp a heated billet from the inner row of the hearth. As the carriage withdraws, the unloader peels release the heated billet, in motion, onto the press feed conveyor (Fig. 4).

The entire automatic operation is synchronized with the indexing of the furnace hearth and is electrically interlocked with the cold-billet storage conveyor. If desired, however, any or all phases of the cycle may be manually operated.

Advantages of the Furnace

Improved forgeability, short-cycle heating and compactness of equipment were important factors in the decision to incorporate this rotary hearth furnace in Eaton's production line. Fast heating of the billet minimizes scale formation on the workpiece, permitting more accurate forging and a cleaner surface. This cuts metal losses and makes possible a reduction in starting billet size. Short-cycle heating results in important savings because of the compactness of the furnace. Comparable conventional heating equipment would occupy considerably larger floor space to deliver equivalent output, with a correspondingly greater chamber volume to heat.

Automatic control and handling eliminate many of the variations attributed to the human element, with the result that all billets are heated uniformly throughout and from one piece to the next. The automatic press line establishes a predictable level of output and improves scheduling of work throughout the plant.

For easy access and minimum downtime when maintenance is required, the furnace incorporates a drop-hearth with screw jacks under its main supporting members. These jacks can lower the hearth about 2 ft. below normal operating position, without removing piping, furnace wall, or the hearth-drive mechanism.

Increased production rates achieved with this press line will enable the division to expand its forging business to serve other Eaton divisions as well as industry in general. Other items expected to be produced eventually will include heavy-duty ring gears, pinions, steering knuckles, spindles, and many other types of forgings that will fit the press table.

Fig. 4 — Heated Billet Is Removed From Furnace and Starts on Its Way to Forging Press

Short Runs

Improving Sample Preparation Equipment

*By JOHN A. MALLAS and ROBERT A. WOODALL**

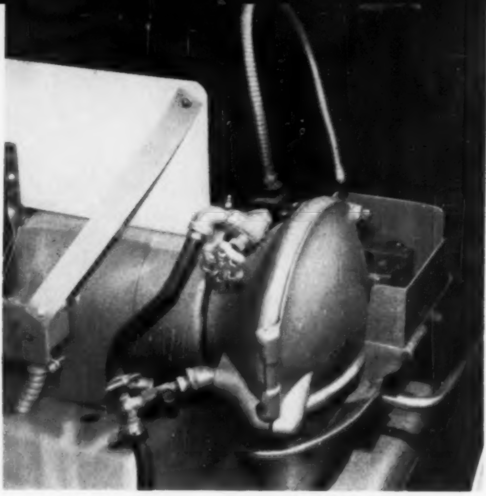


Fig. 1 – Flexible Tube Makes It Easier to Direct Coolant to Specimen in Cutoff. Valves control amount of coolant being delivered

On some occasions, standard pieces of equipment for preparing metallographic surfaces need to be modified to obtain sustained production. Two such modifications in one laboratory have lessened operator fatigue and consistently improved quality of metallographic surfaces. We have modified the specimen cutoff wheel for better and more thorough cooling, and have altered the specimen mounting press to make it more rigid and easier to operate.

Originally coolant was directed to both sides of the cutoff wheel at the rear, away from the cutting edge. With this arrangement, coolant was carried to the piece being cut by wetting and centrifugal action of the wheel alone. Not only were most specimens cooled inadequately, but a fair amount of mist and spattering was generated. As Fig. 1 shows, the setup was modified by interrupting the coolant delivery line before its entrance into the rear wheel housing, and providing an additional delivery path through a gooseneck fitting mounted on top of the wheel housing. Valves, which are plainly visible, were installed in both lines to allow coolant delivery paths to be adjusted.

Figure 2 shows the additions to the specimen mounting press. The platen return spring is a 9-in. coil of 1⅛-in. inside diameter. Made from 5/32-in. diameter wire, this spring, of unknown composition and heat treatment, was picked up in the salvage yard. Although originally installed because one technician could not otherwise lower the platen, it is now considered an indispensable effort-saver. The brace at the rear of the press, another addition, undoubtedly adds longevity to the press and provides a convenient place to store the thermometer. A method for rapid force cooling of the mount assembly is also desirable, and is being devised.

Fig. 2 – Spring on Mounting Press Platform Guide Forces Pressure Plate Down When Pressure Is Released. Mold cooler is also shown on pressure plates

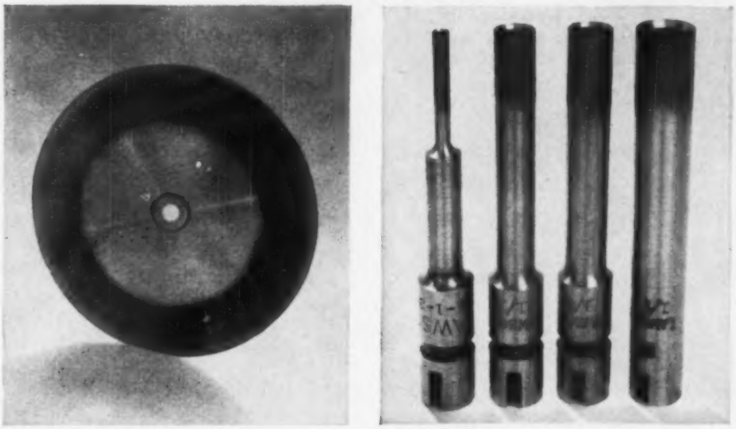
Although not requiring a great deal of ingenuity, these modifications have helped us considerably. Each metallographic laboratory must, of course, select, modify and arrange its equipment to handle its own particular problems. These modifications, however, should be useful in many laboratories dealing with both production and research problems.

*Mr. Mallas is metallographer, Transport Div. Metallurgical Laboratory, Boeing Co., Renton, Wash. Mr. Woodall, formerly at Boeing, is now with Special Metals, Inc., New Hartford, N.Y.

Linde *Coatings & materials* News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Long wear for precision cutting parts now comes in thin coatings —.001" thick



Two important industrial cutting tools whose working lives have been multiplied by LINDE Flame-Plating tungsten carbide coatings: Rubber skiving knives (l.) and paper drills.

SUPER-THIN coatings of tungsten carbide and aluminum oxide—in the .00075" to .002" range of thickness—now keep many industrial cutting surfaces on the job many times longer than previously, yet preserve the precision fit needed for optimum cutting. The result: important savings in downtime and operating costs.

These tough, long-life precision coatings are applied by LINDE's Flame-Plating process, which "blasts" molten particles of tungsten carbide onto specified areas of wearing surfaces until the particles are built up to the desired degree of thickness.

Typical examples of longer wear

Because their cutting surfaces are Flame-Plated with tungsten carbide coating, rubber skiving knives that formerly required resharpening after every shift now stay in use 15 times longer. The knives also have the advantage of a self-sharpening effect. As the softer steel base wears more rapidly than the hard, tungsten carbide coating, a sharp edge is always presented to the material being cut.

Tungsten carbide coating enables serrated knives used in cutting plastic sheeting to process three times as much material before the first re-sharpening is necessary.

A coating of .001" thickness on the inside cutting surface of surgical shears has reduced their rate of wear by as much as 33 percent.

Flame-Plating proved so revolutionary for household cutlery that the manufacturer built his merchandising theme around *"The Greatest Development in 2000 Years of Cutlery Making—a Cutting Edge of Tungsten Carbide."*

Solves many wear problems

Tungsten carbide coatings of micro-inches thickness are equally effective wherever metal parts or working surfaces are exposed to abrasion, galling, erosion, fretting, corrosion, or high-temperature wear. Coatings are applied by the LINDE's 6,000-degree Flame-Plating process without distortion of the work piece or changes in properties of base metals.

For full information on Flame-Plating for your particular application, check and mail the coupon below.

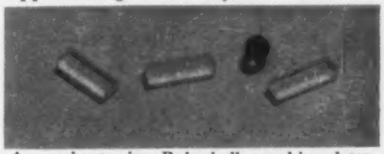
Need to production-polish tungsten carbide surfaces?

It's easy with LINDE metallographic production-polishing aluminas—available in grades for three types of finishing: For high stock removal, 1 micron C; for moderate stock removal and ¼ rms finish, 0.3 micron A; for super polish, 0.05 micron B.

LINDE has developed special techniques for production-polishing of semiconductors and soft metals (such as brass), also new ideas for production-polishing hard metals, including micrometer anvils, hardened bearing races, routine metallographic samples. Get help with polishing techniques to meet your requirements. Send coupon below.

Jet planes landed by ruby-against-sapphire wear pads

In the automatic landing computer of a modern jet interceptor, a tiny ruby ball held to tolerances of 30 millionths oscillates against a synthetic sapphire plate flat to 1/10 light band, as a reference plate for a computer to translate radar approach signals into hydraulic actions.



Approximate size: Ruby ball, sapphire plates.

A similar wear surface bears on the cam head. Certain fly wheel governors also have sapphire wear surfaces.

This 70,000 to 300,000 psi LINDE material has a hardness second only to diamond, unlubricated static friction coefficient of .18, and dynamic of .08 against itself in moderate loads. It is economically suited for wear applications such as gage points, textile guides, optical inspection flats, and flow valves. Send coupon for information.

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Circle 2175 on Page 48-B

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LETTERS TO THE EDITOR

Ultrahigh Strength Steel, Historically Speaking

EUCLID, OHIO

In recent years, great interest has developed in ultrahigh-strength steels having ultimate tensile strengths of 250,000 psi. and higher, along with high yield points and considerable ductility. Of course, these materials are for use in large sections and various shapes, but it is interesting to note that carbon steel wire of very high tensile strength has been known for years. In 1926 Albert Sauveur*, describing patented wire, attributes to J. T. Tinsley a statement that an 0.70% C steel wire can be produced having an ultimate "tensile strength of 400,000 psi., and be sufficiently tough to be wrapped about itself without breaking and be swaged flat to one-half its original thickness without splitting". Even by today's standards such characteristics are very good.

Sauveur states that ". . . to produce wires having a very high yield point and very great tenacity (300,000 to 400,000 psi.) while retaining considerable toughness, the heat treatment is so conducted as to produce sorbite to the practical exclusion of pearlite, free ferrite, or free cementite, and is generally applied to steel wires containing some 0.35 to 0.85% C. . . . To produce sorbite, the cooling through the critical range should be relatively rapid but not so rapid as to cause the retention of martensite or even troostite lest the steel be brittle, nor should it be slow enough to permit the formation of pearlite since this would imply decreased tenacity. Patenting in practice is usually conducted as a continuous operation, the wire being led through the heated tubes of a furnace and cooled by being brought into the air or into a bath of molten lead comparatively cool but seldom below 700° F."

The 1948 A.S.M. Metals Handbook describes patenting as consisting "in heating continuously strands of rod or process wire to a temperature well above the upper transformation point, and then quenching to obtain definite structures and mechanical properties and also to restore the ductility of hard drawn process wire for further reduction. [One type] 'Metallic hardening' or 'MH patenting' consists in heating [thus] and quenching in molten lead at about 1000° F. In 'double lead patenting', practiced mostly on process wire, the steel is both heated and quenched in molten lead". It is interesting to speculate that if either MH or double lead patenting and drawing were carried out in one continuous process with the quenching bath in the neighborhood of the

*The Metallography and Heat Treatment of Iron and Steel, by Albert Sauveur, 3rd edition, 1926, University Press, Cambridge, Mass.

Data Revised for SSS-100 and SSS-100A Steels

Robert White of the Sheffield Div., Armco Steel Corp., Houston, Tex., in a letter to the editor referred to the M-P Fact Sheet on p. 118 of the October issue of *Metal Progress*. Specifically, he calls our attention to SSS-100 steel, saying that this grade is now made in thicknesses from 3/16 up to and including 2 in. and in tensile strength range of 115,000 to 135,000 psi.

Mr. White also stated in his letter that the SSS-100A grade is now capable of maintaining 18% minimum elongation over the entire thickness range instead of the range given in footnote (e).

Our technology certainly moves rapidly and we are happy to publish these revised figures so that the readers of *Metal Progress* can make the above changes in their copies of the October issue, p. 118.

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Letters . . .

700° F. mentioned by Sauveur and with a drawing operation occurring immediately subsequent to quenching, the process would closely resemble the initial stages of the austenite deformation process*. Certainly the results described by Sauveur are equal to the best produced by the austenite deformation process to date.

W. E. McKibben

Still More on Old Razors

Boulder, Colo.

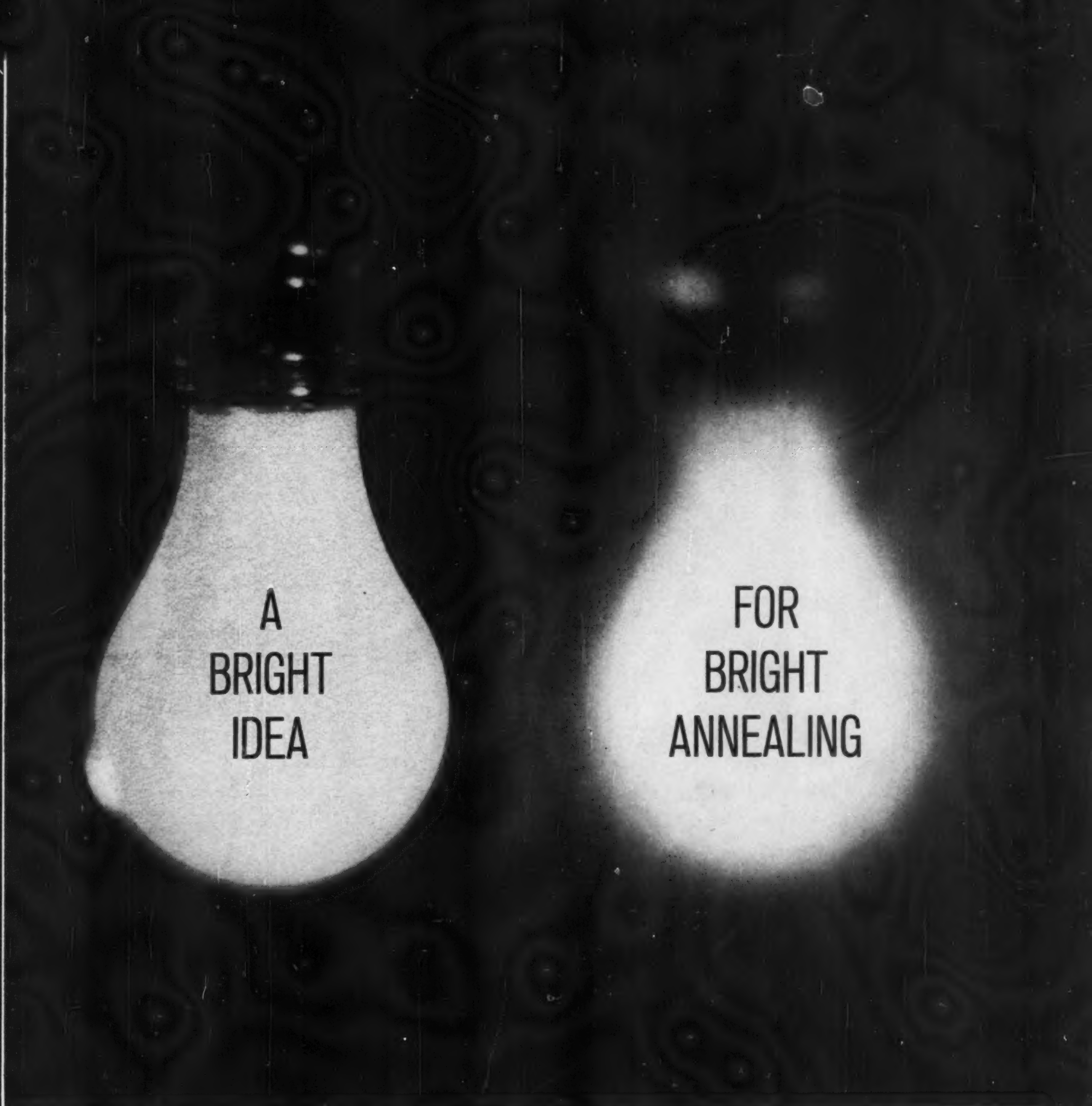
I would like to add some information to the articles in the June and September issues of *Metal Progress* on the old straight-edge razors.

Prior to World War I, some of the best straight razors were made by the combined efforts of both England and Germany. England furnished the forged heat treated blanks, which were then shipped to Germany for grinding. This seemed to make use of the best skills of both countries. When the war came along in 1914, however, it naturally disrupted this arrangement. At the same time, gas warfare resulted in a great demand for razors, since it was necessary to have a clean shaven face for the gas masks to be effective.

After the war, when I attended the University of Sheffield and took some advanced work in heat treating and metallography, I visited a number of plants there, and was shown, with a great deal of pride, machines and devices for grinding straight razors. Of course, the British had been doing some grinding right along and they had a good start. But during the war they had really done a good job producing the straight-edge razors so necessary for all of our armed forces.

I think the variation in hardness and structure from back to edge and lengthwise of the blade can be explained by the method of tempering the blanks after they were hardened. This was done on a copper plate over a flame, the plate being 18 to 20 in. long and wide enough to accommodate the blades. The blades were placed on this plate at one end

*Also called deformation of metastable austenite, etc.



It takes the right atmosphere to develop brightness in stainless steels during annealing. Dry hydrogen will do it, but a dry N_2-H_2 atmosphere from anhydrous ammonia will do it at less cost. It is the *least* expensive way to supply large volumes of gaseous nitrogen and hydrogen for atmospheres that prevent formation of scale and assure a bright, clean finish.

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It is ideal for: annealing nickel and nickel alloys; electrical steels; beryllium copper; silicon copper; and other copper alloys. Dissociated ammonia is excellent for clean hardening of high carbon and high chrome tool steels . . . for copper brazing of all types of ferrous metals . . . for sintering metal powders.

Our experience with ammonia is unsurpassed by any other producer in this field. Allied Chemical flexibility for shipping ammonia in barge, tankcar, tankwagon, tank truck or cylinders fits every user's needs for saving time and labor.

For specifications and local offices, see our insert in Chemical Materials Catalog, page 272A and in Chemical Week Buyers Guide, page 27.

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and gradually moved along so that all would not be finished at the same time. The operator judged the degree of tempering by color. He could also examine the blades and if they were crooked, they could be straightened while at tempering temperature. As blades were taken off one end, they were put on at the other in a continuous operation.

Since the back of the blade was resting against the copper plate, it naturally was tempered more than the edge. This is evidenced by the fact that, when we tried to cut down these larger and worn down straight razors, the results were always the same. If we cut back very far, we found the blade was entirely too soft.

There are still quite a few of these old razors around and most of them need regrinding and shaping up. However, our experience has been that it just cannot be done because the metal gets too soft for shaving purposes.

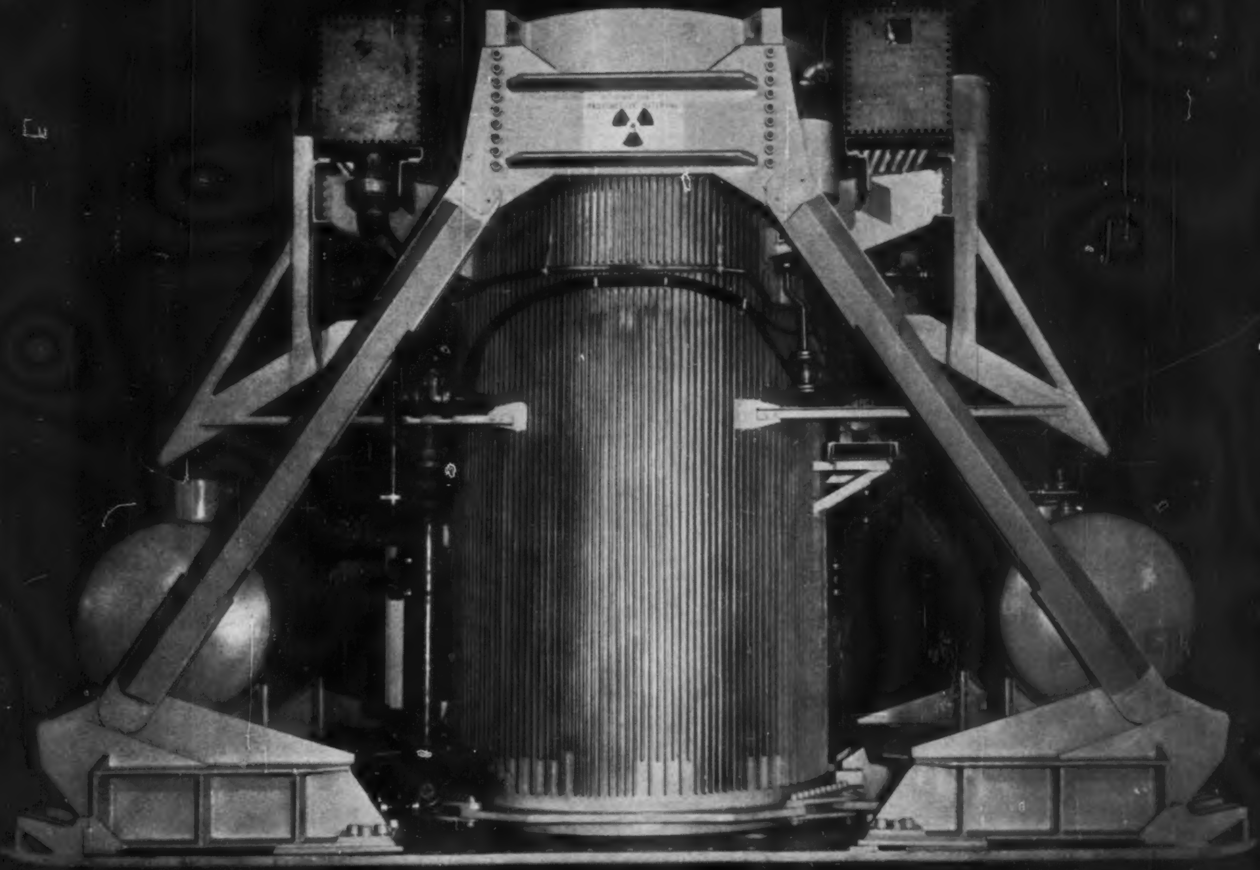
Harlow C. Platts
President
Western Cutlery Co.

Woonsocket, R.I.

As a user of straight-edge razors for over 35 years (until I was given an electric recently), I still insist that one straight-edge razor is worth a dozen electric razors.

In addition to the metallurgical aspects of holding an edge, there is another factor which is seldom considered outside the cutlery industry. This is the thinness of the blade, whether hollow ground or not. The farther you can get from the wedge-like shape of an axe toward a blade thinly ground back from the edge for a long distance, the better the cutting ability, whether shaving or carving. A thin blade also gives the illusion of better edge-holding properties. When I was in the cutlery industry (knives, not razors), a common expression by those who knew cutlery was "give me a good second for a carver", meaning a blade that was too thin for sale to silversmiths. Although the silversmiths knew a good blade, a thin blade could be nicked or the edge turned more easily.

I have found from personal experience that stropping alone resulted



Letters . . .

eventually in a bevel on the cutting edge of a razor. Frequent honing on a flat stone eliminated this, with consequent improvement in cutting and a feeling of better edge-holding ability. I believe that the honing thinned the back of the razor sufficiently to allow the cutting edge to lose this bevel, or wedge shape, a few thousandths back.

I maintain that, while metallurgy is important in a razor, sharpness and edge-holding ability depend on shape, section size and geometry as well. I feel, too, that the often heard remark, "A stainless steel carver made from 440C does not hold an edge as well as the old fashioned straight-carbon one", is due more to shape and thickness than to metallurgical factors.

WALTER M. SAUNDERS, JR.
Metallurgical Director
Taft-Peirce Mfg. Co.

Materials Research . . .

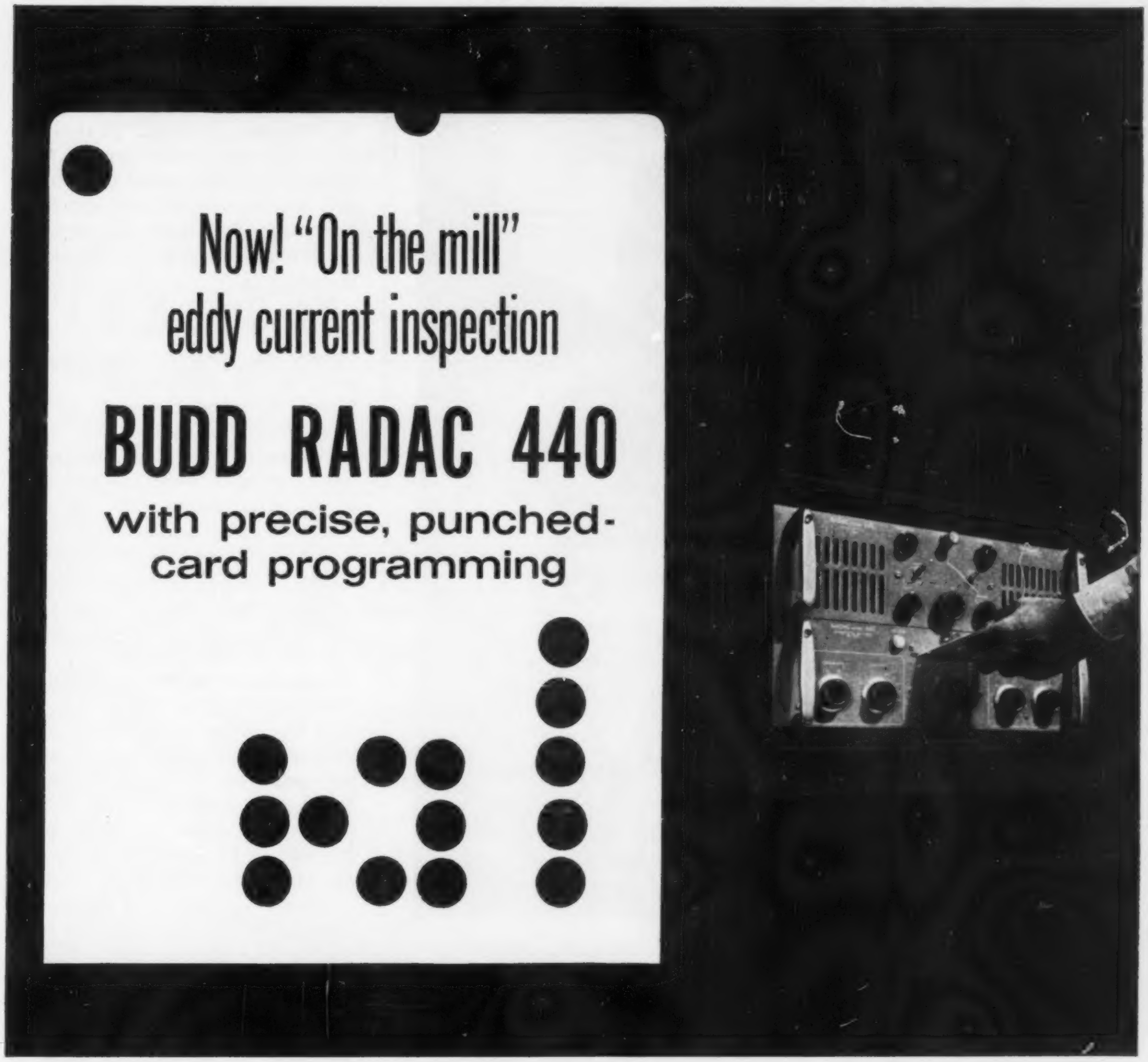
(Continued from p. 106)

the ALSOS Mission.* I have already written about the Jubilee of his institute in *Metal Progress* (January 1960, p. 142). I also reported the electron emission microscope of Prof. H. Düker. At a later date he told me more about it and I would like to see one of them employed in this country to take advantage of its special features. Their new "Special Metals Institute" under Dr. E. Gebhardt is going strong so we may soon have some fine contributions in that new field.

Studies on Crystal Slip

In Munich I met Prof. Heinz Borchers again – the last time was in 1945 in Weihan Stephan. He is the son of Geheimrat Borchers who was one of a small group which started Germany on its scientific career in metallurgy. In Prof. Borchers' laboratory I first learned of Dr. Kaiser's piezoelectric method of studying and recording phenomena of plastic deformation and phase changes. Crystal slip, even below the "elastic limit", is observed, although once that occurs and the load

*ALSOS was a secret Army mission — its purpose was to contact German scientists.



Budd's new model 440 Radac now enables precise, automatic eddy current inspection to be applied under production-line conditions by production-line personnel. Proved in a wide range of "on the mill" installations, the Radac 440 can be used to detect surface and internal cracks, seams, laps, splits, holes, inclusions, weld defects and other types of discontinuities . . . in tubing, bars, flat stock and many other shapes over a wide dimensional range. All types of metals can be inspected. New saturation accessory allows testing of ferrous as well as non-ferrous metals. Results are independent of variations in dimensions, wall thickness, temperature, chemical composition, residual stresses and other variables.

The Radac 440 is an advanced, multiple-frequency eddy current flaw detector programmed by punched card. Only general knowledge of eddy current principles is required for reliable operation. With the punched cards accurately defining inspection requirements, responsibility for reproducibility of results is placed in the instrument . . . thereby greatly reducing the possibility of human error.

The Radac 440 features a striking array of exclusive new features in addition to punched-card programming. Full information on the 440 and other versatile Radac equipment is yours on request. We'll be glad to demonstrate Radac eddy current inspection in your plant.

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Materials Research . . .

is released, no additional signals are recorded until that stress is exceeded on subsequent loading. (I thought then that the availability of this method could have saved much time and expense when welded ship failures were first being investigated by showing that steel was primarily the culprit.)

While I was in Munich, I met Dr. Weigel at the University who showed me his new laboratory for studying rare earths and their compounds as well as other exotic metals of reactor metallurgy.

For me a visit to Berlin was mandatory, since it is the home of one of my alma maters. My old professors had all departed but I found a new and active group as replacements. The old Technische Hochschule, renamed the Technical University, is nearly completely rebuilt – inside as well as outside.

I also visited the Bundesanstalt für Materialprüfung at Berlin-Dahlem. This brought up an interesting incident associated with Adolf Martens, cofounder of metallography with Sorby. As students at the Technische Hochshcule in 1912, Paul Merica and I went religiously to the old Materialprüfungsamt in Dahlem to attend the lectures of Geheimrat Martens on testing materials. He was founder and director of the institute. Upon writing to Prof. M. Pfender, the present head, to arrange a visit, I mentioned that earlier experience. Much to my surprise I received word that I was the only survivor who had known Martens and was asked to write my personal impressions for their archives.

Prof. Pfender is carrying on in fine style, with the notable addition of strong sections for nondestructive testing and basic investigations in specific fields.

New Fatigue Testing Machine

In the testing field I was greatly impressed by a new design of fatigue testing machine which can handle anything from small wire to huge crankshafts. These machines use the vibrating principle which was devised, I believe, by R. Weck of the British Welding Research Association. (An article by Dr. Weck, on Soviet welding developments, based on a trip to the U.S.S.R., will ap-

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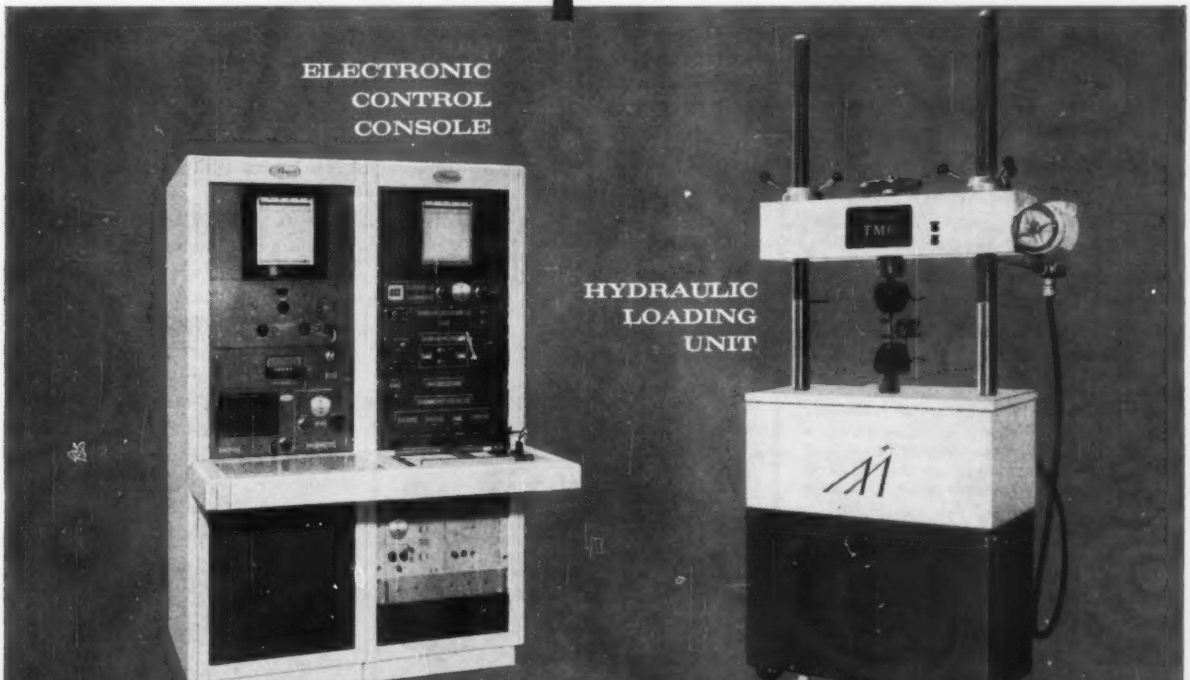

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Materials Research . . .

pear in the Tenth International Issue of *Metal Progress* next month.)

Nondestructive testing is a live subject in Germany. A knotty problem is that of identifying ultrasonic signals from defects, coarse grains, segregations and the like.

Plasma research is followed both theoretically and experimentally by a small group in Germany. The former is headed by Prof. G. Ludwig at the Free University Berlin. The objective is understanding plasma and boundary layer phenomena in support of the applied research. Apparently the study of re-entry problems is of special interest though the theories are not yet ready to define the properties which materials must have for the best performance.

Research in Scientific Metallurgy

The new Frankfurt laboratory of Metallgesellschaft would be of special interest to those who are interested in research by industry. Large and adequately equipped with the tools of modern research and development, it is under the direction of Dr. Max Hansen, well known here as a member of the Armour Research Foundation and now a director of Metallgesellschaft. His work exemplifies an approach to the "new metallurgy" with emphasis on facilities for scientific research.

High on the list of research institutes is the famous Max Planck Institut für Eisenforschung at Düsseldorf. Prof. Franz Wever is now a "Senator" of the governing body of all Max Planck Institutes and his successor as director is my old friend Prof. Willy Oelsen. I asked for my instructor in microscopic technique at Charlottenburg, Dr. (h.c.) Angelica Schrader, referring to her as "queen of metallographists". Prof. Oelsen said the "queen" would come soon but that I must also meet the "crown prince", a young man who would soon take over her position. I can only say that the young man has some large size shoes to fill (with due apologies to Dr. Schrader, who is petite) but he has what we call "desire".

The work in electron microscopy and on the identification of tiny precipitates is excellent and supports work in other divisions. One example is the broad investigation of fatigue

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by Max Hempel. This also illustrates the "team work" which is supplanting the solo performance of individuals. For example, the electron microscope technique is needed to determine the precise way that the fatigue crack initiates. Dr. Hempel has a large-scale study of fatigues in progress, including fatigue and superimposed creep at elevated temperatures. This is shedding light on how composition, dislocations and the fine points of structure affect metal behavior.

Research on Steel at Krupp

When I visited the Krupp works in Essen some years ago, it was a hideous ruin, but it is now back in business (although not in munitions) as a symbol of Germany's recovery. The main steel laboratory is at Rheinhausen, while the Krupp research laboratory at Essen is associated with the Widia plant. A large portion of the research program consists of studies of plant and development problems under the director, Dr. Otto Rüdiger. Steel quality and production costs are always important – I believe that explains a major effort on deoxidation practice and reaction products.

A feature was the recovery and examination of products which do not remain in the steel. From the detailed studies of ion nitriding and spark machining, it would appear that technological processes of their complexity require great effort for full exploitation in practice. Other interesting work was that on titanium and its alloys, the formation of passive films, vapor pressure and reactions at high temperatures. They also produce stainless tubing for reactor applications with a 0.004-in. wall which was said to perform better than zirconium.

A highlight was a visit with Dr. Josef Hinnüber, director of Krupp's Widia plant. We had never met but we had a grand time reminiscing on Carboloy of General Electric and Widia of Krupp. We were in good accord and well pleased with our early recognition of the potential value of the (then) new tool and die material and our association with its technical and commercial development. He recalled my 1928 paper on Carboloy given at the A.S.S.T.

Circle 2187 on Page 48-B

(now A.S.M.) meeting in Philadelphia.

Many more visits were made covering a wide range of subjects. In Hanover, Prof. Alexander Matting studies fatigue and the progress of the fadigue crack, aluminum welds, gray iron welds, thermal shock, galvanizing versus internal stresses, reactor corrosion, weld metal with a low E value, quality of spot welds, flame plating and bonding, glass fiber reinforced plastics.

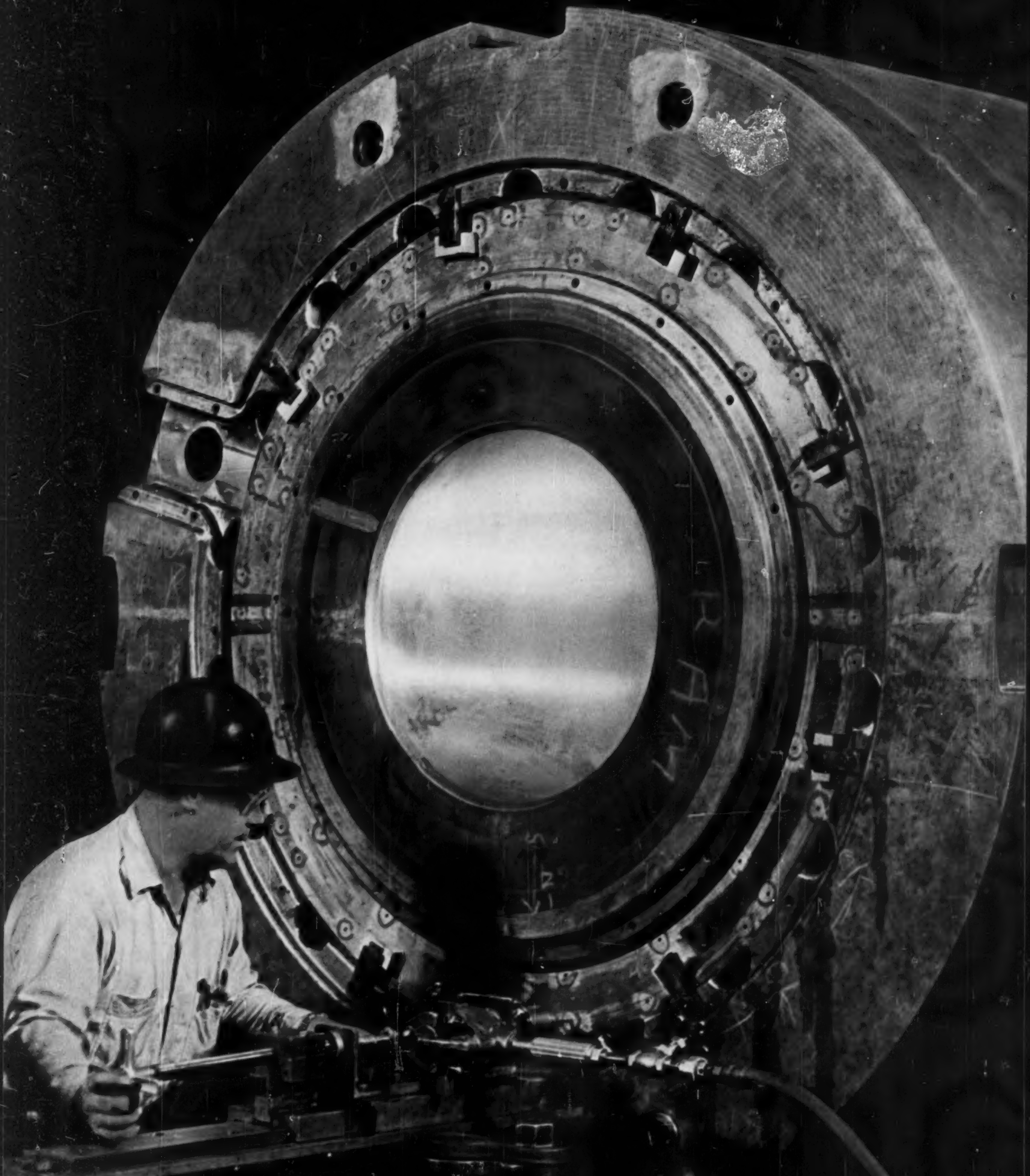
At Braunschweig, Prof. E. Justi works in metal physics, on cryogenic behavior, ultrahigh magnetic fields, zone melting, metal whiskers, effects of gases on metals, a quick method for establishing TTT diagrams and transformations on continuous cooling while fuel cell development has been a special interest. Prof. W. Hofmann studies cold welding in great detail, explosive welding, and other welding problems while he has a device which records temperature and shrinkage simultaneously as the HAZ of a weld cools.

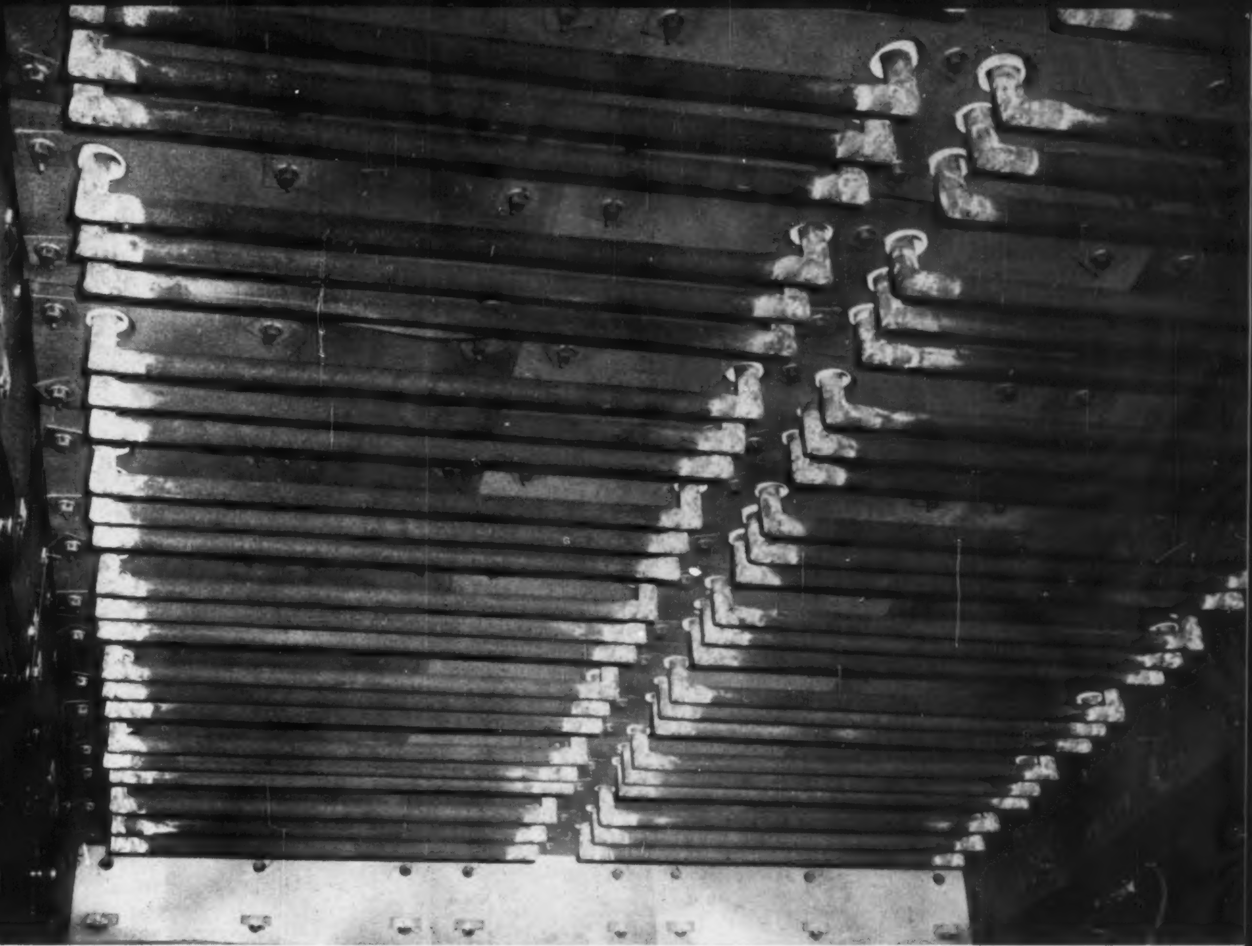
Prof. Günter Wassermann in Clausthal, well known for his work on structure, headed the Vienna meeting of the German Metallurgical Society (Institut für Metallkunde) which dealt with structure and grain boundaries. His research oriented this way, but he is enlarging his facilities to handle a broader program.

At the University of Göttingen I witnessed the passing of the famous laboratory of Tammann and Masing. The chair was occupied by Prof. R. Vogel who was Tammann's assistant at the time of my first visit there in 1912 but he is retiring. He has determined numerous ternary diagrams and is very proud of the accuracy with which he calculated the dimensions of the core and crust of the earth from pertinent constitution diagrams. His work on phosphorus and sulfur diagrams helps to understand the conditions for obtaining steel of greater purity. The new or replacement laboratory at Göttingen is devoted to metal physics and dislocations.

Metallurgy of Explosive Forming

The metallurgical faculties in Aachen are headed by Prof. Hermann Schenck, who is also president of the Verein Deutscher Eisenhüt-





U-shaped GLOBAR® elements used in unique vacuum brazing furnace

Brazing of stainless steel honeycomb aircraft and missile structures is handled at Grumman Aircraft Engineering Corp. by a unique vacuum furnace, manufactured by F. J. Stokes Corporation. The new equipment eliminates the need for enclosing the work in an air-tight metal envelope, saves better than $40,000 a month in the cost of argon gas previously needed for inert-atmosphere brazing and results in work with enhanced physical properties.

The success of the unit depends in large part on the flexibility of furnace design made possible by GLOBAR silicon carbide electric heating elements. The photo above shows the under side of the upper heating frame, with its 60 specially designed U-shaped GLOBAR elements. This is hydraulically lowered on a bed frame, similarly equipped with 60 additional GLOBAR units. The work is sandwiched between the frames. Sealing the two sections provides the furnace chamber, which is evacuated to a pressure of less than 0.5 microns.

Controls provide 10 transverse heat zones throughout the 6′ x 10′ length of the furnace. Temperature is precisely regulated during the various cycles of soaking, brazing, cooling and re-heating to produce the desired physical properties. Brazing temperature is 1640° F. Development of this unique furnace opens a wide field of possible applications in handling difficult brazing and heat-treating problems. It also emphasizes the unusual potentialities of electric heating with GLOBAR elements. Why not investigate their advantages for your particular job? Consult your furnace builder or write to Refractories Div., Globar Plant, Dept. MP-121, Carborundum Co., Niagara Falls, N. Y.

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- Standard straight-type elements shipped from stock or within two weeks.
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- Type AT elements 4″ to 105″ in length.
- For greater economy in heat treating, brazing, forging, melting and sintering.

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Circle 2191 on Page 48-B

tenleute. His laboratories reflect a wide range of interests from the new melting and foundry laboratory to metal physics. Prof. Schenck was away at the time of my visit but Prof. Schmidtmann, head of the steel section, showed me their facilities for all kinds of steel research. A new departure is their program on explosive forming; he hopes to isolate the properties and characteristics which a starting material must have for this method. As at other universities, the approach to steel research is sophisticated compared to the past. An example is their study of case carburizing and the influence of ultrasonics and internal stresses.

The theoretical load at Aachen is carried by Prof. K. Lücke. (He spent a year at Brown University and discovered a charming American who is now Frau Prof. Lücke). His field is metal physics and he has a sizable program. Structure and dislocations play a prominent role yet the problems are technically important, such as recrystallization, boundary effects and grain growth, technical deformation and forming processes, damping and radiation damage and the effects of radiation on phase equilibria.

Prof. F. Bollenrath is also at Aachen. He is the German representative on the Structures and Materials Panel of AGARD, the advisory group for air and space research and technology which was established by Prof. von Karman.

Most other visits were equally impressive but I will mention only one more, to Dr. F. Förster. He had recently built a second plant for production and uses his first one largely for development.

During similar visits in Sweden, Spain, Belgium, Austria and Switzerland, I found both examples of the "old" or conventional work and also new laboratories and younger staff members for work in the "new" metallurgy. There are many new materials and applications, while service conditions of stress, temperature and operating mediums are both new and severe. Due in part to our support of research and in part to interest in the problems, workers in these countries operate very similarly to their fellow workers elsewhere.

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PERSONAL MENTION

Henry H. Hausner

HENRY H. HAUSNER, well-known for his work on nuclear materials and powder metallurgy, has been appointed to the staff of the Ilikon Corp., Natick, Mass. Ilikon Corp. was formed about one year ago with emphasis on space materials and their fabrication. Its ultrahigh vacuum equipment permits outer space simulation for practically any testing purpose. The new types of materials now developed by Ilikon are for high-temperature applications, but work is also planned in development and production of materials for nuclear uses. Dr. Hausner's background includes investigation of powder metallurgy of reactor metals at Sylvania Electric Products Corp., Bayside, L. I., and more recently powder metallurgy work as vice-president at Penn-Texas Corp., New York.

He received his metallurgical education in Vienna and later took charge of the laboratory of Elix A. G. there, one of Austria's leading incandescent lamp factories.

Immigrating to America in 1940, he worked with American Electro Metal Corp. for three years and then joined General Ceramics and Steatite Corp. as chief engineer. Here he attempted to combine ceramics and metals, and as a result published one of the first papers on "cermets". Turning from cermets to powder metallurgy, he joined Sylvania Electric Products Corp., in Bayside, L. I.

Active in technical societies not only here but abroad, he is president of the International Plansee Society for Powder Metallurgy of Reutte, Austria. He also finds time to act as adjunct professor at the Polytechnic Institute of Brooklyn.

James K. McLaughlin – from assistant division manager to vice-president in charge of the Youngstown Div., Ajax Magnethermic Corp., Youngstown, Ohio.

Franz R. Hensel – from vice-president of engineering for P. R. Mallory and Co., Inc., Indianapolis, Ind., to executive vice-president of Clyde Williams and Co., Columbus, Ohio, and president of the Clyde Williams Corp., an international company providing research, technical information, investment advisory and management services in the United States and Europe.

Charles H. Harton – from Cleveland district manager to Florida manager for Carpenter Steel Co., Reading, Pa.

Robert William Freeman – now wire metallurgist in the Colorado Fuel and Iron Corp., Buffalo, N.Y. plant.

Harold J. Read

At its 48th annual convention in Boston, the American Electroplaters' Society presented to HAROLD J. READ, professor of physical metallurgy at Pennsylvania State University, the Charles Henry Procter Memorial Leadership Award. The award, including an honorarium of $150, is made for "distinguished leadership and conspicuous deeds furthering the objectives of the Society, enhancing its value to industry, branches and members, and expanding its dignity, prestige and progress". Dr. Read studied at the University of Illinois, receiving his bachelor's degree in 1934 and his master's in chemistry the next year. He went on to the University of Pennsylvania as a graduate student and assistant instructor and received his doctorate in physical chemistry in 1939. He remained at the University as an instructor in electrochemistry and quantitative analysis until 1940 when he went to the Mellon Institute in Pittsburgh. His work there tended more and more

Personals . . .

toward metallurgy and in 1945 he accepted a post at Pennsylvania State University as associate professor of metallurgy, and was appointed professor of physical metallurgy in 1951.

Robert A. Lubker — from director of research and development to vice-president of research and development, Alan Wood Steel Co., Conshohocken, Pa.

Bentley Brown — transferred from manager of the technical division at Northwest Nitro Chemicals Ltd., Medicine Hat, Alberta, to Terre Haute, Ind., where he will continue his work with the parent company, Commercial Solvents Corp. Mr. Brown was secretary of the Medicine Hat Chapter.

Roger L. Hosfield — from chief engineer, Grieve-Hendry Co., Inc., Chicago, to product manager of the oven division of Hevi-Duty Electric Co., division of Basic Products Corp., Watertown, Wis.

J. T. Wood — from warehouse manager in Miami, Fla., for Crucible Steel Co. of America, Pittsburgh, to tool steel development engineer for Crucible's Atlanta, Charlotte, Miami and Tampa sales branches, with headquarters in Miami.

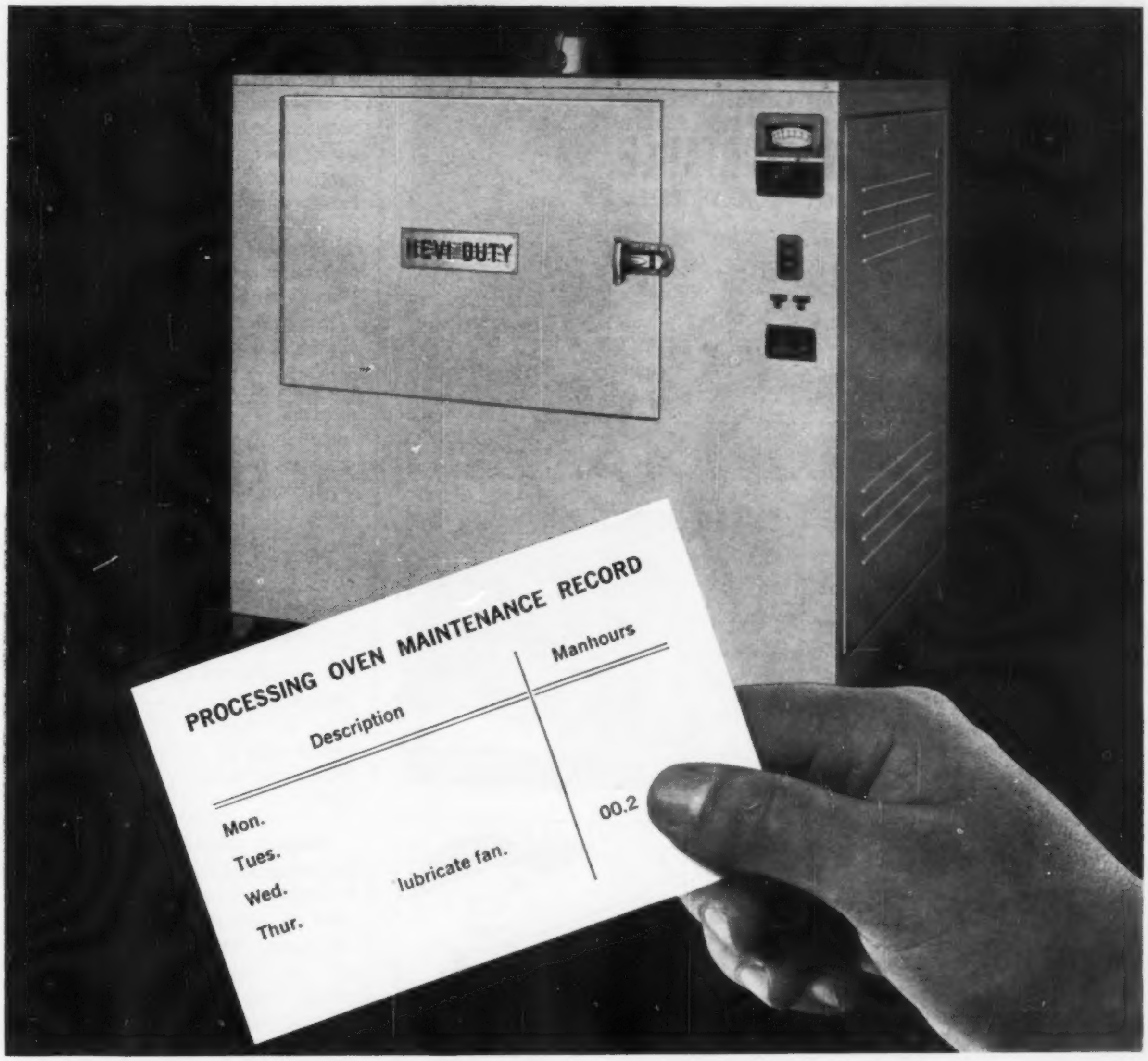
Louis Kettler — appointed research engineer on the staff of American Zinc Institute-Lead Industries Association expanded research program in New York.

Charles P. McShane — from customer technical service engineer for the Midwest area to manager of technical services, tool steels, for Crucible Steel Co. of America, Pittsburgh.

Clarence C. Hanson — from vice-president in charge of sales to vice-president and general manager of the Trenton (N.J.) Div. of Ajax Magnethermic Corp.

Jerome J. Kizior — joined Taussig Associates, Chicago, as chief metallurgist.

Julius R. Toth — elected secretary of AT Electronics, Inc., New Haven, Conn., a newly formed subsidiary of American Tube Bending Co. He will also serve as comptroller.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Personals . . .

Phillip H. Booth – from manager of alloy sales to manager of carbon bar, rod and wire sales for Youngstown Sheet and Tube Co., Youngstown, Ohio. He will continue to handle sales of alloy bars.

Donald G. Harter – from director of engineering, York Div., Decatur Works of Borg-Warner Corp., to vice-president, research and engineering, Kodiak, Inc., St. Paul, Minn.

Ernest R. Ramirez – from senior research scientist at General Electric's metallurgical products department in Detroit to senior research supervisor for Special Metals, Inc., New Hartford, N. Y.

W. R. Clough – appointed associate professor of materials engineering at Rensselaer Polytechnic Institute.

Edward B. Evans – from assistant professor in metallurgy, Case Institute of Technology, to research metallurgist at Tapco, a division of Thompson Ramo Wooldridge Inc., Cleveland.

Michael Tenenbaum – from assistant general manager in charge of technical services to general manager of research and quality control for Inland Steel Co., Chicago. At the same time, **James J. Halley,** formerly superintendent of the experimental iron smelting project, was named manager of research and development, succeeding **Edwin D. Martin,** who is retiring from active assignment – he will remain as a consultant to Inland until the end of the year.

Harold J. Holmes – from manager, general engineering of the Heald Machine Co., Worcester, Mass., to chief engineer for Sciaky Bros., Inc., Chicago.

A. R. Johnson and **Daniel H. Yates** – appointed manager and assistant manager, respectively, of the research department of Vanadium-Alloys Steel Co., Latrobe, Pa.

Frederick C. Kroft – from works manager to staff assistant to the president, Haynes Stellite Co., a division of Union Carbide Corp., Kokomo, Ind.

Circle 2200 on Page 48-B

Metals Engineering DIGEST

Interpretative Reports of World-Wide Developments

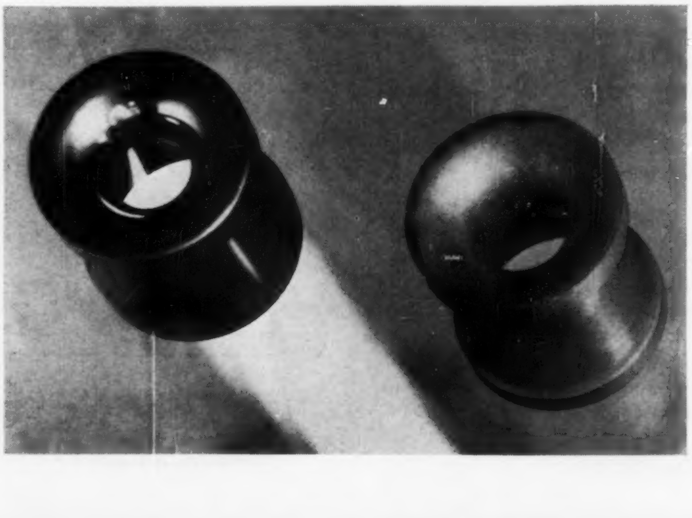
Carbon and Graphite—Their Uses in Metallurgy

Known chiefly for their use in electrodes for electric arc furnaces, carbon and graphite have many properties which make them desirable in other industrial areas. Through advanced processing methods, stronger, more heat-resistant grades are constantly being developed.

THIS PAPER, in presenting much data on fabricated carbon and graphite, shows them to be versatile engineering materials. Used in most industries, particularly in the metallurgical field, they have a unique combination of physical and chemical properties (see box, p. 142). Among other factors, their electrical conductivity may be varied by a factor of 100, mechanical strength by at least 10, thermal conductivity by 30, and thermal expansion by 5 or more.

To begin with, divergence in properties is caused by processing

Fig. 1 – High Density (Left) and Conventional Graphite. Note difference in porosity and finish



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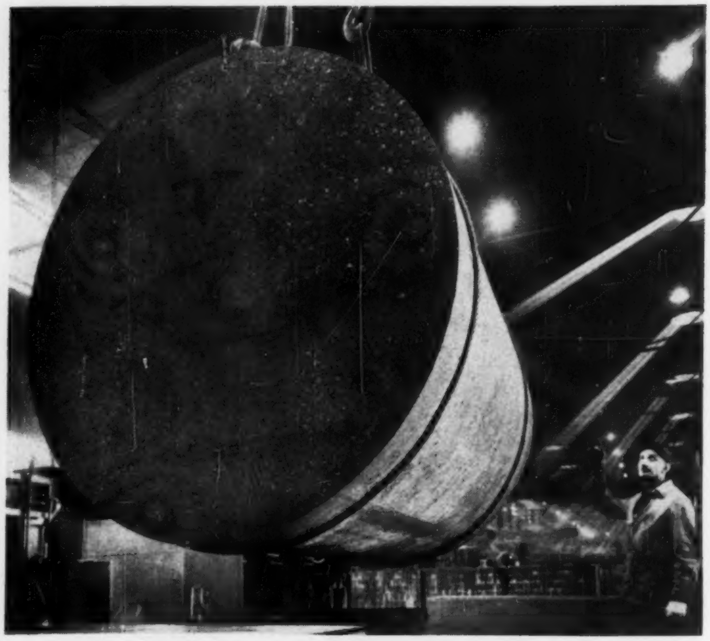

Electrode for Submerged Arc Furnace, 63 In. in Diameter and 84 In. Long

variables which result in differences primarily in purity, density, grain size and crystal orientation. Thus, the employment of different types of petroleum coke (for the raw material) allows variations in most properties by a factor of about two. Still greater property variations occur when less commonly used starting materials, such as lamp black or anthracite, are employed. Also, forming methods greatly influence the degree of orientation and hence the degree of anisotropy in properties. Thus, the ratio of many properties with and across the grain in extruded graphite is twice that for molded graphite.

In manufacture, the degree of baking is a fundamental factor. Carbon grades are baked at "low" temperatures, such as 1000° C. (1830° F.), to carbonize the bond, but graphite grades are heated to the range 2600 to 3000° C. (4710 to 5430° F.). This extreme heat causes the randomly oriented carbon crystals to grow and change to a more ordered pattern of stacked parallel planes, increasing density and strength as well as producing marked anisotropy of properties.

Uses of Carbon and Graphite

The largest single use of these two materials is in electrodes for arc furnaces. Submerged arc furnaces (used in melting ferroalloys, titanium and zinc) generally employ carbon electrodes, while open arc furnaces (used for steel, iron and some nonferrous alloys) generally employ graphite. Having greater strength, graphite electrodes can carry greater electrical loads. With the development of the "pitch reservoir" connecting pin for such electrodes, joint loosening has been eliminated and joint conductivity has improved.

As for other uses for graphite, it is employed for resistance furnace parts, molds for casting, thermocouple parts, extrusion guides, furnace brazing jigs, tubes for injecting materials to be dispersed in a hot metal bath, and missile and rocket nozzle parts.

High-purity graphite is also used in many areas of nuclear technology because of its excellent moderator and reflector properties, and its good strength up to 1800° C. (3270° F.). When exposed to radiation, graphite becomes stronger and harder. Although irradiation below 150° C. (300° F.) causes some distortion of the graphite lattice, applications usually involve higher temperatures. These provide an annealing action that largely eliminates irradiation changes.

New grades of graphite with im-

Reinserting a 14-foot HK nickel-chromium alloy furnace tube at Security Engineering, Inc., Division of Dresser Industries, Dallas, Texas, after its regular six-month inspection. Upon refiring, these heavy-walled tubes bend back into their normal shape and function perfectly.

Security Engineering Proves Furnace Tubes Last 2 Full Years at 1800°F

CAST NICKEL-ALLOYED RADIANT-HEATER TUBES KEPT IN SERVICE 24 HOURS A DAY, 7 DAYS A WEEK

Fired by a mixture of air and natural gas, these HK* alloy (26% Cr–20% Ni) tubes provide temperatures up to 1800° F inside a carburizing furnace. But HK alloy can take it because . . .

HK alloy resists oxidation, sulfidation, and carburization. These properties team up with HK alloy's high-temperature strength and ductility to provide Security Engineering with two years of trouble-free service. Moreover, HK alloy tubes are easily cast and readily available.

Casting Alloys to fit your application. HK alloy is only one of a complete range of alloys designed for heat-treating service at temperatures ranging from 1200° F–2200° F. Each alloy provides good surface-film stability, strength, and ductility at high temperatures. And some of these alloys offer ease of welding or resistance to thermal shock. So whatever the heat-treating application, there's a nickel-containing casting alloy to do the job.

How to select the proper heat-treating alloy. "Heat Resistant Castings, Corrosion Resistant Castings...Their Engineering Properties and Applications" discusses the entire range of heat-resistant casting alloys, and advises what to consider in choosing the right alloy for your needs. A post card will put this 72-page booklet on your desk.

*Alloy Casting Institute designation

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proved properties or characteristics suited for special applications are constantly being developed. For example, some high-density graphites are being developed; so far, experimental grades have better strength, permeability and finish than conventional graphites now available. Figure 1 illustrates the differences between the two types. Potential application of these materials is in the missile field where resistance to high-temperature erosion is a critical need in such components as rocket nozzles and nose cones.

Some Properties of Carbon and Graphite

- Resistance to severe thermal shock.
- Low thermal expansion.
- No deformation at high temperatures.
- Strength increases with temperature.
- Wide selection of thermal conductivity.
- Not wet by most molten metals – no sticking.
- Resistance to abrasion and erosion.
- Resistance to practically all corrosives over a wide temperature range.
- Freedom from metallic contamination.
- Freedom from corrosion scale formation.
- Easily machined and fabricated.
- Good electrical conductivity.
- Self-lubricating.
- Lightweight – easily handled.

Still higher strengths and densities are being obtained in pyrolytic graphite, as material produced by thermal decomposition of a hydrocarbon gas on a hot substrate. Degree of orientation and properties approach those of natural graphite; a high degree of anisotropy is also present.

M. W. Hawkes

Digested from "Carbon and Graphite in the Metallurgical Industries", by Neal J. Johnson, V. J. Nolan and J. W. Shea. Paper presented at the Annual Meeting of the Metallurgical Society of A.I.M.E., St. Louis, February 1961.

Ductile Iron . . .

(Continued from p. 98)

but raised the tensile strength slightly in irons tempered above 1100° F.

Yield strength curves of the various experimental irons closely parallel those of the tensile strength values. As with the tensile strength, the effect of silicon and manganese on the yield strength is a function of their roles as matrix strengthener (silicon) and carbide stabilizer (manganese) and the temperability (or lack of it) which they lend to the iron.

As for the elongation values, they are, in general, consistent with the yield and tensile strength values. In other words, elongations increased as strengths decreased with increasing tempering temperature. Tempering at 1100° F. or greater was necessary to raise the elongation values to 5% and above.

When modulus determinations were made on tensile specimens of each composition tempered from 400 to 1250° F., the calculated values showed satisfactory consistency, and heat treatment within the ranges studied. The range of values was 20,800,000 to 24,100,000 psi., the average being 22,800,000 psi.

Photomicrographs in Fig. 10 (p. 98) demonstrate the influence of composition on the resistance to tempering at high temperatures (1200° F., in this instance). As is apparent in the structures that represent 0.26% Mn irons with varying silicon contents, the higher-silicon irons (3.64 and 4.12%) are greatly influenced by tempering, containing fairly large spheroids of carbide in a ferritic matrix for most of the areas. The structures of irons containing 2.24 and 2.45% Si more closely approach the fully tempered martensite of steels. Needles of free ferrite, which are scattered throughout the matrices, are more pronounced in the 2.45% Si iron.

Most resistant to tempering are the higher-manganese irons. To illustrate, the 0.68% Mn iron has an acicular structure of tempered martensite with a few small needles of ferrite, and the iron with 1.10% Mn contains a matrix of fine tempered martensite without any areas of free ferrite.

These structures correlate with the tempering behaviors reported in

the previous section. It will be recalled that the higher-silicon irons softened drastically at 1200° F., that the lower-silicon, low-manganese irons showed considerable softening at 1200° F. but did not temper as much as the higher-silicon types, and that the higher-manganese irons maintained considerably more resistance to tempering exhibiting higher hardnesses.

Some Important Conclusions

On the basis of the results, the following conclusions seem warranted concerning the ductile high-carbon, nickel-free irons which were the subject of this study.

- Manganese, in amounts between 0.26 and 1.10%, lowers the upper and lower critical temperatures, but silicon, in contents between 2.24 and 4.12%, raises them.
- Silicon is relatively effective in closing the gamma (austenite) phase field of the constitution diagram for iron-carbon-silicon with low amounts of manganese.
- Manganese has a major role in increasing the depth of hardening of the ductile irons that contain moderate amounts of silicon. Silicon, on the other hand, is almost completely ineffective in altering the hardenability of the irons with low-manganese contents.
- The introduction of over 4.0% Si produces a bainitic nose in the isothermal transformation diagram of a high-carbon ductile iron with a small amount of manganese.
- Silicon, in the range of 2.24 to 4.12%, increases the temperability of the iron with little manganese, but manganese in amounts between 0.26 and 1.10% seems to render the tempering reaction more sluggish.
- Through quenching and tempering, tensile strengths in the order of 240,000 psi., with yields of 210,000 psi. and elongations of 3% can be achieved. Silicon seems more effective than manganese in achieving these high strengths.
- The presence of silicon increases the drop in strength with increasing tempering temperature, while the presence of manganese retards the same drop.
- The effects of silicon and manganese can probably be attributed to the fact that silicon is a ferrite strengthener and manganese is a carbide stabilizer.

Coatings of Titanium Nitride Protect Graphite at High Temperatures

A vapor-plated TiN coating, which transformed to TiO_2 in a Mach 2 air jet, prevented damage to a graphite surface during a 60-sec. test; unprotected graphite was severely damaged after 20 sec.

GRAPHITE, ALTHOUGH POSSESSING comparatively good strength at elevated temperatures, is subject to extreme oxidation damage above 1250° K (1800° F.) in air. The practical utilization of this material thus depends upon finding a stable coating to protect its surface.

Since the high-temperature oxides of graphite are gaseous, no inherent protective mechanism is possible in reaction with the atmosphere. However, if the surface is coated with a material which will form an impervious oxide, the graphite will be protected from atmospheric attack.

Of the various processes available, vapor plating appears most applicable to coating graphite. The vapor-plated coating, which is deposited on the substrate from a gaseous atmosphere, can be varied in properties and thickness by controlling the process temperature along with the flow rate and chemical analysis of the gases.

In the present study, graphite specimens (cylinder with a hemispherical end, 3/4 by 3/16 in. diameter) were coated with TiN from an atmosphere of $TiCl_4$, H_2 and N_2 according to the reaction,

$$TiCl_4 + 2\,H_2 + \tfrac{1}{2}\,N_2 \rightarrow TiN + 4\,HCl$$

Tank hydrogen containing nitrogen as an impurity was bubbled through the liquid $TiCl_4$ and passed over the graphite surface at 1475° K. (2190° F.). A coating time of 12 min. yielded a TiN coverage of about 40 micron thick when the flow rate was about 1.6 l. per min.

Coated and uncoated specimens were tested at Mach 2 in a supersonic, ceramic-heated air jet having a stagnation pressure of 7.14 atm. and an estimated stagnation temperature of 2250° K. (3595° F.). Surface temperatures were measured with an optical pyrometer, the general appearance of the coating being

Coatings . . .

recorded by motion pictures. The TiN coating was converted to TiO_2 (verified by x-ray diffraction) with a 60% volume expansion according to the reaction;

$TiN + O_2 \rightarrow TiO_2$ (rutile) $+ \frac{1}{2} N_2$

During 60 sec., the coated specimens attained a surface temperature of about 1700° K. (2600° F.) and were protected, while the uncoated specimens reached 2165 to 2200° K. (3434 to 3500° F.) at the surface and were destroyed. The coating completely protected the graphite if the TiN thickness exceeded 20 mg. per sq.cm. Thinner coatings failed at the stagnation points (not the sides). Additional experiments involving weight changes under completely stagnant conditions at 1680° K. (2570° F.) confirmed the results of the supersonic jet. The stagnant air tests indicated a minimum thickness of about 26 micron thick for protection, but a direct comparison between the two types of tests is not possible.

Theoretical Considerations

Consideration of the critical characteristics for a coating which is to be converted to a refractory oxide leads to the following general rules:

1. The Pilling-Bedworth ratio pertinent to the original coating-oxide transformation should exceed unity, but be small enough to prevent the tendency toward spalling of the oxide.

2. The thermal expansion coefficients of the substrate material, original coating, and the final oxide product must be compatible at all temperatures of use to prevent cracking.

3. The oxide should form rapidly to prevent interim substrate damage particularly when the substrate oxides are gaseous.

4. The coating should be thick enough to protect, but thin enough to minimize thermal shock difficulties.

5. The oxide should remain solid, or at least in a highly-viscous liquid state under the operating conditions.

6. The thermodynamics of proposed systems should be investigated using compilations of standard thermodynamic data. The enthalpy of the reaction (original coating to oxide) should not be large enough to cause damage to the substrate surface or unreacted original coating. The unprotective oxide should be stable relative to an oxide of the substrate under the operating conditions.

Other coatings such as silicon and boron-based layers may also be of the protective-oxide type. The basic conditions listed should apply to any coating formed as a result of the interaction of the substrate or the intermediate layer with an environment.

Digested by M. J. FRASER from "Titanium Nitride: an Oxidizable Coating for the High-Temperature Protection of Graphite", by N. T. Wakelyn, NASA Technical Note D-722, February 1961, NASA, Washington, D.C.

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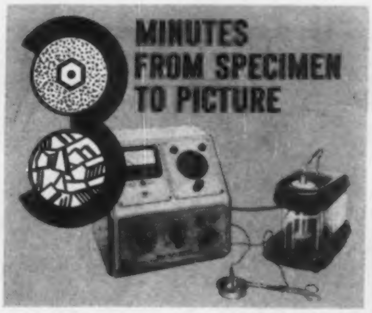

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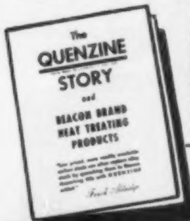

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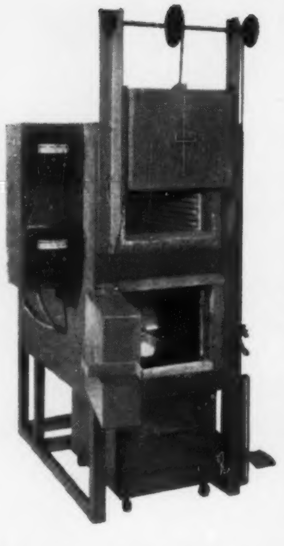

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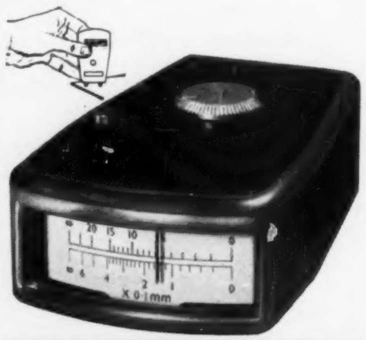

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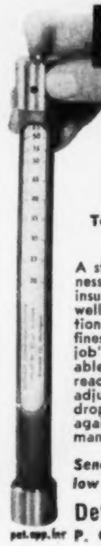

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Refractory Metals in Europe—a Growing Field

Molybdenum, columbium, tantalum and tungsten are of great interest in Europe, though there is less activity than in the United States.

THOUGH THE EUROPEANS are less active in the refractory metals field than the Americans – apparently because of a lack of confidence in the future requirements of new applications in such areas as jet engines, nozzle liners, and re-entry vehicles—there is much interest. The major requirements for refractory metals come from the lamp and electronic industries where the chief new applications involve rhenium. Ultrahigh-temperature thermocouple and electron tube parts using rhenium and tungsten-rhenium alloys are being produced in England, France and Germany. Interest is also apparently high in Russia where the Bajkov Institute has published most of the phase diagrams of rhenium with the other refractory metals, and has conducted laboratory studies on alloying behavior, recrystallization, and applications of the metal.

Corrosion-resisting equipment is a major application for tantalum in Europe. However, much interest is also being shown in columbium, since its lower density and potentially lower cost would be an advantage. The British are using columbium in reactor applications where they have to contend with corrosion by liquid sodium.

Turning to the area of research and development, England is particularly active. At Murex and the University of Sheffield, studies on columbium involve physical properties, strain aging, oxidation resistance and the development of alloys and coatings resistant to oxidation. Important work on the theory of alloys using the hydrogen-pressure method is being done at the University of Birmingham, and the work on electronic interactions at General Electric has been particularly noteworthy. The Associated Electrical Industries Research Group has active programs on phase diagrams, substructure, and deformation mechanisms; the B. S. A. Research Center at Birmingham is concerned with oxidation-resistant alloys and coatings. Though American activity in molybdenum for ramjet and turbine components has slackened, interest is high in England and France.

American research on refractory metals as liners for solid-fuel rocket nozzles and re-entry vehicle leading edges, on the other hand, apparently has little parallel in Europe. An observation in Russia of fabrication of sheet molybdenum and tantalum, but not tungsten, may indicate that they are chiefly interested in refractory metals for radiation shields and chemical plant equipment.

At the Max Planck Institute and at the University of Freiberg, both in Germany, research includes work on the effects of interstitials on the properties of tantalum, along with studies on the compounds of columbium and tantalum with nitrogen, oxygen, and carbon. Metallwerk Plansee in Austria is working on nonmetallic dispersions in tungsten and phase diagrams of intermetallic compound systems. As a note, a process developed there for coating molybdenum in a metallic copper-silicon bath has given

Refractory Metals . . .

protection up to 200 hr. in air at 1600° C. (2900° F).

Research in France has involved studies on oxidation-resistant coatings, on the oxidation of columbium, and on the hydrogen embrittlement of tantalum. In Russia, there are research activities on phase and recrystallization diagrams of rhenium, on the alloying of columbium, and on the powder metallurgy of molybdenum, tungsten, rhenium, tantalum and columbium.

Turning finally to the field of production, Europe has excellent facilities for refining and fabricating refractory metals. Tantalum and columbium are produced mainly by electrolytic and carbothermic processes. There are many producers of tungsten and molybdenum powder, employing the well-known hydrogen reduction process. (European producers rely more on powder metallurgy techniques and less on vacuum melting than do those in the United States, incidentally.) Columbium and tantalum ingots are consolidated generally by sintering in vacuum. Metallwerk Plansee, a leader in the field, sinters ingots of molybdenum up to 800 lb. in hydrogen muffle furnaces at 1750 to 2000° C. (3200 to 3600° F.), as well as tungsten blocks up to 50 lb. at 2500° C. (4550° F.) in bell-type furnaces. These are used as sheet bar for wide sheet and for large forgings for rocket motor linings in the United States.

Metallwerk Plansee appears to have the leading position for fabrication of large-size mill products of refractory metals. They have rolled 18 in. wide tungsten sheet and are constructing a 125-centimeter, two-high mill which is to be used for sheets up to 40 in. wide. They have also cooperated in fabricating tungsten sheets 40 in. wide and 50 in. long with hand sheet mills in an alloy steel plant. Tungsten ingots from Plansee have been swaged to cylinders about 6 in. in diameter. Most of the other refractory metal companies of Europe have narrow-gage mill facilities and require collaboration with a steel mill to produce large mill products.

Digested by M. W. HAWKES from "Refractory Metals in Europe", by R. I. Jaffee, DMIC Memorandum 83, Feb. 1, 1961, Battelle Memorial Institute, Columbus, Ohio.

Circle 2251 on Page 48-B

Cadmium Plating Can Embrittle Ultrahigh-Strength Steels

To be certain that ultrahigh-strength steels are not embrittled by hydrogen during cadmium plating, stringent testing is needed.

ANTICIPATING FUTURE Air Force requirements for environmentally protected steels with tensile strengths in the 280,000 to 300,000 psi. range, researchers have undertaken an extensive program of evaluating hydrogen embrittlement effects of cadmium plating on A.I.S.I. 4340 and a selected tool steel of the H11 type. The dead-load, notched tensile test was selected as a basis for evaluation because it was believed that the applied stress could be most accurately computed and reproduced in this test. A notch radius of 0.025 in. was used, and all specimens were plated to 0.3 mil cadmium thickness.

Groups of samples were plated in a conventional cadmium cyanide bath with a proprietary brightener, in a cadmium fluoborate bath containing peptone, and in a cadmium sulfamate bath with catechol as a grain refiner. Additional samples were plated without a brightener, and other specimens were coated using cadmium immersion solution and vacuum metallizing techniques. Specimens were baked at 375° F. ±25° prior to testing. Selected specimens also were subjected to various corrosion tests, salt spray and outdoor exposure.

Results of the experimental program established the following:

1. The sustained load test proved to be an extremely sensitive way to determine hydrogen embrittlement.

2. Cadmium plating from a fluoborate bath, generally accepted as a nonembrittling system, caused embrittlement failure.

Preferred Test Procedure

A preferred test procedure was also developed for evaluating hydrogen embrittlement:

1. Machine four specimens (min.) of same material which is to be evaluated, and process them through the same heat treatment.

2. Plate them with the production process.

Cadmium Plating . . .

3. Test the plated specimens axially at 75% of the ultimate notch tensile strength of the untreated metal for a minimum of 200 hr. If any specimen fails, the plating is considered a failure.

Other findings, and observations on hydrogen migration, bath throwing power and corrosion test results, are presented by the authors.

Digested by J. L. Wyatt from "A New Look at the Hydrogen Embrittlement of Cadmium-Coated High-Strength Steels", by Norman M. Geyer, G. William Lawless and Bennie Cohen. *Proceedings*, American Electroplaters' Society, 1960, p. 143-151.

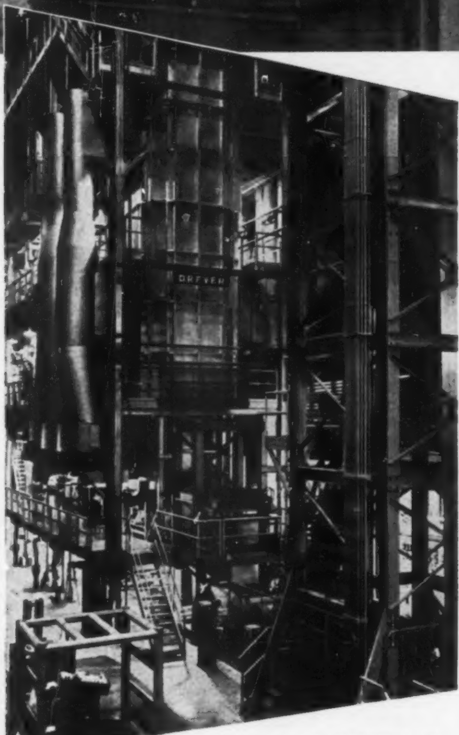
Many Uses for Lithium

Lithium, the lightest metal, rose from obscurity in little more than a decade and entered a period of spectacular growth.

Lithium, a metal with many essential military and important civilian applications, is found in many minerals; spodumene, lepidolite, petalite, and amblygonite are the most important. The compound dilithium-sodium-phosphate, which is recovered from brines of Searles Lake, Calif., is the fifth important source.

Lithium is used in the form of compounds more than as the metal. A principal use is in special glasses, ceramics, and enamels; compounds are important because of their ability to fuse at relatively low temperatures. Low-melting enamels are useful for thin sheet steel products because the lower firing temperatures minimize warping. They are also used for decorating aluminum.

Other lithium compounds are also useful. For example, lithium carbonate is converted to stearate to make "all-purpose" greases (which retain lubricity through wider extremes of temperatures than conventional greases). Lithium chloride and lithium bromide are employed in air conditioning and industrial drying, lithium hydroxide is used as a catalytic agent in the Edison nickel-iron storage battery, and lithium fluoride and chloride can function as components of fluxes for melting, weld-



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Circle 2256 on Page 48-B

Uses for Lithium . . .

ing and brazing of aluminum and magnesium.

Lithium metal has been employed as an alloying element in aluminum, magnesium and lead, and as an oxide and gas scavenger in copper alloys and stainless steel. (Digester's Note: The new aluminum alloy, X2020, which contains about 1% Li, has higher strength and modulus of elasticity and a lower density than other high-strength aluminum alloys such as 7075 and 2024. Magnesium-lithium base alloys containing up to 15% Li have lower densities than any present commercial metal.)

Starting in 1955, large quantities of lithium hydroxide were purchased by the A.E.C., which was extracting the Li^6 isotope for undisclosed reasons. The residue, lithium hydroxide rich in Li^7, was stockpiled with the intention that it would be repurchased by the producers over a period of time. The A.E.C. purchases made it necessary for the lithium industry to expand its capacity tremendously. However, in 1959 and 1960, the A.E.C. contracts were terminated, and at the present time the lithium industry has considerably more capacity than is necessary. What is needed now is an expansion and intensification of research on new uses for lithium.

Digested by P. D. Frost from "Lithium", by Albert E. Schreck, a chapter from Bulletin 585, Mineral Facts and Problems, 1960 Edition, Bureau of Mines, U. S. Dept. of Interior, Washington, D.C.

Zn Coatings Keep Cb From Oxidizing at Elevated Temperatures

Above 450° F., zinc coatings form intermetallic compounds with columbium which will protect the base metal to 2050° F.

About two years ago, engineers at the Naval Research Laboratory discovered that zinc coatings impart oxidation resistance to columbium at elevated temperatures. Numerous studies of protection mechanisms, coating techniques and thermal ranges of applicability have since been completed. The paper summarizes factual information which has been developed to date on the protection phenomenon.

Zinc forms a series of intermetallic compounds with columbium. The oxides of the two metals also exhibit compound formations and high solubilities. Three eutectic mixtures have been identified in the Cb_2O_5-ZnO system. The solubility of zinc is extremely limited, both in columbium and in the oxide compounds of the two metals.

Zinc may be applied to columbium by vapor distillation, dipping, electroplating or cladding followed by diffusion. Compound formation, which follows a parabolic rate equation, develops most rapidly at 1450° F. The $CbZn_3$ which is formed remains stable to 1890° F., at which point it decomposes to $CbZn_2$. At 2050° F., $CbZn_2$ decom-

poses; above this point the zinc vaporizes, and all protective properties disappear.

Air oxidation of zinc-coated columbium is comparatively slow; if the sample is preconditioned at 1600° F., useful life is estimated at 1000 hr. at 1800° F., and 20 hr. at 2000° F. for a 6-mil coating.

Zinc compound coatings on columbium exhibit remarkable self-healing properties. The mechanism of healing is thought to be as follows:

1. Columbium is oxidized to Cb_2O_5.
2. Zinc vapor rapidly permeates the Cb_2O_5, and oxidizes on the surface to form a protective layer of ZnO at the Cb_2O_5-air interface.
3. Additional zinc reacts with columbium at the Cb-Cb_2O_5 interface to form a layer of $CbZn_2$.

In actual thermal cycle tests between 1000 and 2000° F., zinc-coated strip specimens survived 50 cycles without significant contamination of the base metal. These tests were run in air with a stream velocity of 45 ft. per sec.

Additions of aluminum, titanium and zirconium to the zinc coating appear to enhance its protective properties on columbium, but self-healing characteristics are impaired. However, the most significant variable is the thickness of zinc compound which is formed in the coating process; an increased thickness produces longer specimen life.

The review paper includes phase and diffusion diagrams, and cites eight authors on the subject.

Digested by J. L. WYATT from "Zinc Coatings for Protection of Columbium From Oxidation at Elevated Temperatures", by W. D. Klopp and C. A. Krier, DMIC Memorandum 88, March 3, 1961, Battelle Memorial Institute, Columbus, Ohio.

Ductile Tungsten Can Be Made

According to this report, tungsten rods become more ductile when they are electropolished to depths of 0.005 in.

ONE OF THE MAIN FACTORS limiting the use of tungsten is its lack of ductility at room temperature. Since it is known that the mechanical properties of tungsten bars are affected by the conditions of their surfaces (among other variables), experiments have been performed to determine the nature of some of these surface factors.

Among other things, researchers examined different methods of surface preparation. Beginning with sintered and swaged tungsten rods, commercially pure and ⅛ in. diameter, they ground some of the rods to a 16 micro-in. average rms. surface. The remainder of the swaged tungsten rods were dipped in sodium hydroxide to produce a 23 micro-in. average rms. surface. Then, the surfaces of selected bars from each group were either electropolished or ground. Amount of material removed from the surfaces of the rods by both methods varied from 0.001 to 0.005 in. reduction of diameter.

When both electropolished and ground bars were submitted to bend tests in an Instron machine, electropolished specimens exhibited marked increases in ductility over the ductil-

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N-A-XTRA 90 plates and bars are used in the "Ranger," a rough terrain military vehicle designed, developed and fabricated jointly by the U. S. Army Quartermaster Corps and the Clark Equipment Company, Battle Creek, Michigan. The Ranger series is manufactured by the Industrial Truck Division of Clark Equipment Company.

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Circle 2259 on Page 48-B

Ductile Tungsten . . .

ity of the as-received bars. However, bars which had merely had their surfaces ground exhibited no great increase of ductility over that of the as-received swaged bars. For the next step, electropolished bars which had exhibited increases in ductility were scratched by emery paper; this greatly reduced the ductility achieved by electropolishing.

Electron microscope examination of electropolished surfaces indicated that surface roughness decreased significantly as increasing amounts

Fig. 1 – Effect of Surface Removal by Electropolishing on Ductility of Tungsten Rod Specimens. As received material bends 17° (top); material with 0.003 in. removed, 38° (middle); and material with 0.005 in. removed, 155°

of material were removed by electropolishing. However, when brittle rods were electropolished, this action did not result in a marked increase in bend ductility. Thus, ductility was improved by removing surface material by electropolishing, but not by grinding. Apparently, removal of impurities by removal of surface layers is not the major cause of increased ductility. Reference to Fig. 1 supports the major conclusion that removing the surface of tungsten specimens by electropolishing increases the room-temperature bend ductility. Further, it can be seen

that a definite correlation exists between amount of surface removed and the increase in the bend angle. In fact, the latter increases as much as sevenfold with reductions in diameter of 0.005 in. by electropolishing. Apparently, surface roughness is an important factor.

Digested by DAVID KRASHES from "An Exploratory Investigation of Some Factors Influencing the Room-Temperature Ductility of Tungsten", by Joseph R. Stephens. N.A.S.A. Technical Note D-304.

Aluminum Alloys for Reactors

As substitutes for Zircalloy-2 in reactors, Al-Ni-Fe alloys are not suitable, according to this work.

THIS INVESTIGATION was intended, in the words of the author, "to review our knowledge of the corrosion and mechanical properties of the best aluminum-nickel alloys that have so far been developed, and to assess these in relation to Zircalloy from the viewpoint of reactor economics". Apparently, this aim was accomplished. At the end of the investigation, the researchers concluded that the aluminum-nickel-iron alloys were unattractive for use in water-cooled power reactors.

Though the aluminum alloys had good corrosion resistance, the sheathing plate of aluminum would have to be considerably thicker than that of the Zircalloy. Since Zircalloy has also dropped in price, the aluminum alloys were dropped from consideration. However, the test results are of value.

A large number of tests were made involving the following three aluminum alloys: No. 155 (0.5 Ni, 0.5 Fe, 0.2 Si, 0.001 Ti); No. 157 (2.0 Ni, 0.5 Fe, 0.2 Si, 0.001 Ti) and No. 185 (0.6 Ni, 0.5 Fe, 0.2 Si, 0.19 Ti). All of these had less than 0.06% of any of the following – beryllium, zirconium, copper, magnesium, manganese and zinc. Before corrosion testing, the samples were annealed at 450° C. (840° F.) for 1 hr. and air cooled. Then they were pickled for 10 min. in 5% NaOH, 30 sec. in strong HNO_3 and 1 min. in 20% H_3PO_4. After each pickling step, the specimens were thoroughly rinsed in water, and immediately before testing they were degreased in acetone. (*Cont'd. on p.* 173)

Carbon/Graphite Facts for METALLURGISTS

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MISSILES and ROCKETS

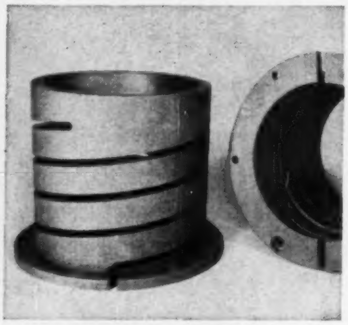
conquer heat with non-melting NATIONAL graphite

NATIONAL graphite, which is created by thousands of degrees of heat, has more useful properties for aero-space heat-resisting applications than any other material. Rocket nozzle inserts, vanes, and other components withstand temperatures of 5000° F in fractions of a second. Graphite not only maintains dimensional stability, but gains strength as temperature rises. Light, *non-melting* graphite is the top answer to spacecraft thermal needs.

Circle No. 2245 on Page 48-B

HEATING ELEMENTS

for resistor-type furnaces performing up to 3000° C.



HEATING elements employing NATIONAL graphite provide excellent thermal, electrical, and mechanical advantages. Graphite elements can be fabricated to almost any configuration. The more common configurations are: hairpin or slotted plate type resistors and tubular and helical units that provide maximum resistance and require minimum space. Special shapes are readily available from NATIONAL CARBON's completely equipped machine shops.

Circle No. 2246 on Page 48-B

GRAPHITE CRUCIBLES

shapes and sizes produced to your requirements

A wide variety of materials can be effectively melted—by electrical resistance, induction, or radiation—in crucibles of NATIONAL graphite. Most molten metals do not attack graphite and are not contaminated by it. Typical applications include: melting of aluminum alloys, exotic and precious metals, and quartz. NATIONAL CARBON can supply crucibles up to 61" in diameter.

Circle No. 2247 on Page 48-B

GRAPHITE

available from fine powders to multi-ton blocks

WHATEVER your stock requirements in graphite, National Carbon Company—the nation's most experienced graphite producer—can meet them with a wide variety of "off-the-shelf" square, rectangular, and cylindrical shapes, as well as fine-to-coarse powders and particles. Stock is available in quantity and a variety of grades—ready to be machined by your own equipment or, better still, by NATIONAL CARBON's skilled craftsmen in our modern machine shops.

Circle No. 2248 on Page 48-B

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UNION CARBIDE

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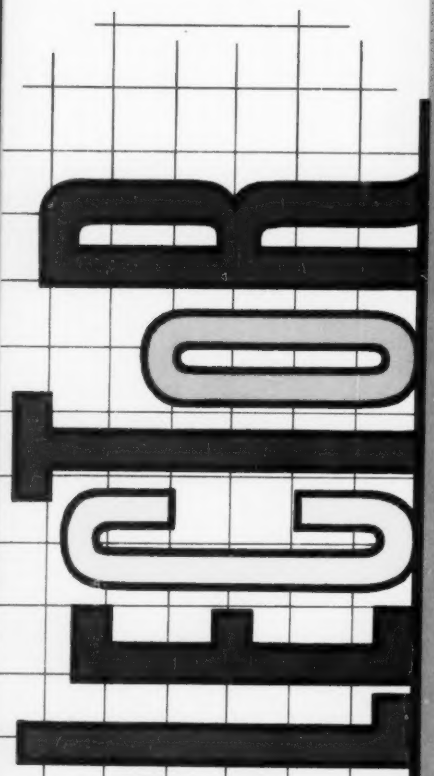
End Your Tool Steel Problems with the A-L STEELECTOR System



Save Selection Time, Insure Accuracy, Cut Inventory Costs

If you started using the new Allegheny Ludlum STEELECTOR Program first introduced last year, you know what savings it can bring. If you didn't, your competitors may have stolen a march on you.

There are many advantages in the STEELECTOR system. Perhaps most important is the savings in selection time. No longer need anyone spend hours in tool steel selection. By using one of the STEELECTOR Cards, an accurate selection can be made virtually at a glance. In seconds you can choose the tool steel grade with the particular combination of red hardness, abrasion resistance, size stability, toughness, and machinability required by the job at hand.

You can select STEELECTOR tool steels with confidence—they are always in stock. You don't have to stockpile tool steel. Instead, by relying on Allegheny Ludlum material and using STEELECTOR grades, you can reduce the variety of tool steels in your inventory. You reduce problems because the STEELECTOR offers the tool steels that are right for your jobs, eliminates those that contribute nothing but confusion.

STEELECTOR Cards Save Selection Time

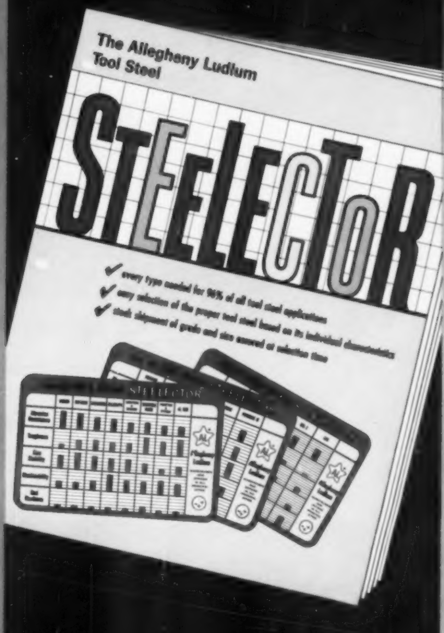
The three STEELECTOR Cards insure that you will pick the right tool steel for every application. Each STEELECTOR Card (there are cards for tool room, hot work, and high speed applications) uses bar graphs to indicate the relative abrasion resistance, toughness, size stability, machinability, and red hardness of the STEELECTOR grades. You can select the best combination of properties for the job at hand virtually at a glance.

STEELECTOR tool steels will meet your job requirements. You can clean house with the STEELECTOR Program. No longer need your stockroom be cluttered with small stocks of scores of grades. No longer need you find yourself holding grades that require different processing, yet give the same results. And you never need to worry about running short. Allegheny Ludlum STEELECTOR grades are always in stock.

STEELECTOR Program Ends Supply Problems

Huge warehouse stocks back up Allegheny Ludlum's STEELECTOR Program. You know before you order that the grade you have selected is in stock, in the size you choose. Here's how the STEELECTOR System works:

First, you select the right tool steel for your job by using a STEELECTOR Card. Then you check the STEELECTOR Data Stock List for the particular grade selected best for your job. (There is a List for each of the 18 STEELECTOR grades.) All sizes and shapes in stock are listed along with hardening, tempering, and annealing temperatures. The List also gives the typical analysis of the steel, its AISI number, and describes its properties. Typical applications are listed along with suggested working hardnesses to confirm your selection.



Free Booklet Explains the STEELECTOR System

You will find a complete description of the STEELECTOR Program in this colorful 10-page Allegheny Ludlum booklet. It tells how the STEELECTOR System helps you pick the right tool steels, save time, and end your supply worries.

Each of the STEELECTOR grades is listed in the booklet along with its description, applications, and AISI type number. Included are three handy STEELECTOR Cards that will save you time in picking the right steel for tool room, hot work, and high speed applications. Everyone who helps select tool steel needs this booklet. For your free copy ask your A-L representative, or write: Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pennsylvania. Address Dept. TS12.

What Can The A-L STEELECTOR Program Do For You?

Whether you are president, purchasing agent, stock room supervisor, engineer, or heat treater, you will find the STEELECTOR System can save you time, reduce costs, and make your job easier. Check this list and see how the STEELECTOR System can help you:

Owner, president or vice president. Reduces costs in warehousing, purchasing, and inventorying. Insures selection of the right tool steel—prevents misapplication and wrong heat treatment.

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Engineer or metallurgist. Speeds selection of the right tool steel . . . saves the time formerly spent in selection for jobs that need it.

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Purchasing agent. Reduces paperwork and inventory needs.

To learn of all the benefits of the A-L STEELECTOR System, ask for the STEELECTOR booklet described in the adjoining column. 3397

ALLEGHENY LUDLUM

LINDE ELECTRIC WELDING

PLASMARC

New...very-thin, fused deposits with controlled dilution
New...high-speed, dross-free cuts in 5-in. thick metals

LINDE, inventor of plasma arc processes, announces *new* PLASMARC weld surfacing and *advanced* PLASMARC cutting. What is plasma arc? It is a flow of gas forced through an electric arc, constricted in a small-bore torch nozzle, and accelerated to form an intense jet. It combines electrical heat with the latent heat of highly-excited ionized gas atoms to reach one of the highest known metal-working temperatures (30,000° F.). It will melt any known metal.

A TRUE WELD

PLASMARC *weld surfacing* is true welding—not coating or plating—achieved by feeding powdered metal through the plasma arc into a weld puddle which freezes to form the deposit. Its precision eliminates excess buildup—ideal for such parts as valves, plowshares, seals . . .

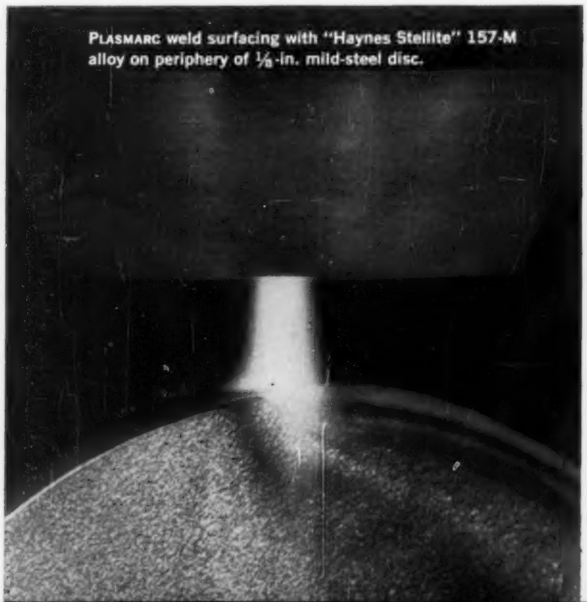
PLASMARC weld surfacing gives precise control of penetration of overlay metal into base metal—as little as .005 in. or higher. Gives precise control of dilution with base metal—from 5% up to 50%. Provides one-pass deposits as thin as .010 in., as thick as 3/16 in., with a wide range of metals and alloys. Produces widths from 1/8 in. to 1 in. or more, speeds over 20 ipm at 95% deposition efficiency, flatter and smoother deposits than other fusion processes.

4000 FT./SEC. VELOCITY

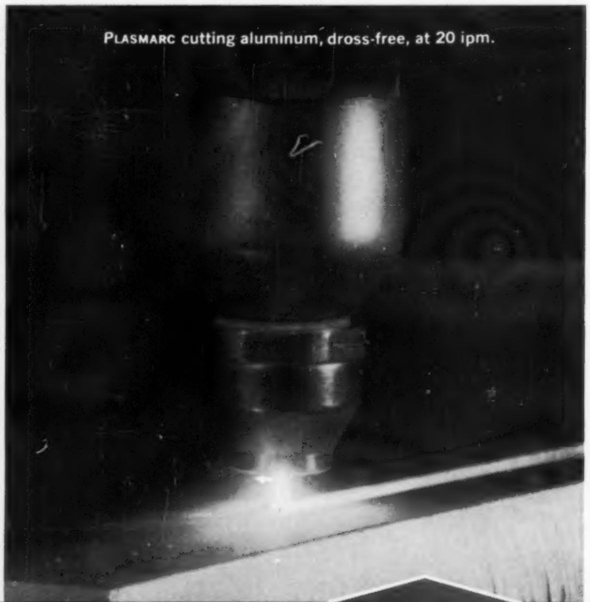
PLASMARC *cutting* uses a near-sonic velocity plasma jet (4000 ft./sec.). It easily melts-and-forces a narrow kerf through both ferrous and non-ferrous metals with little or no change in metallurgical properties. After six years' success, it is replacing shearing, sawing and powder cutting—slower methods which often require machining of the cut edge.

PLASMARC cutting has been further developed—heavy-duty equipment, higher current capacity—to handle increased metal thicknesses. It cuts aluminum, magnesium and copper up to 5-in. thick and stainless steel up to 2 in. thick, dross-free. It clean-cuts 4-in. thick stainless, nickel, carbon steel (requires no iron powder), "Monel," "Inconel," cast iron, high-alloy and clad steels. It makes precise, high-speed cuts up to 300 ipm, holds tolerances to 1/16 in., leaves a heat band as thin as .006-in. wide.

Get full details . . . see a "live" PLASMARC demonstration. Contact your local LINDE office or write direct.



PLASMARC weld surfacing with "Haynes Stellite" 157-M alloy on periphery of 1/4-in. mild-steel disc.



PLASMARC cutting aluminum, dross-free, at 20 ipm.

LINDE COMPANY
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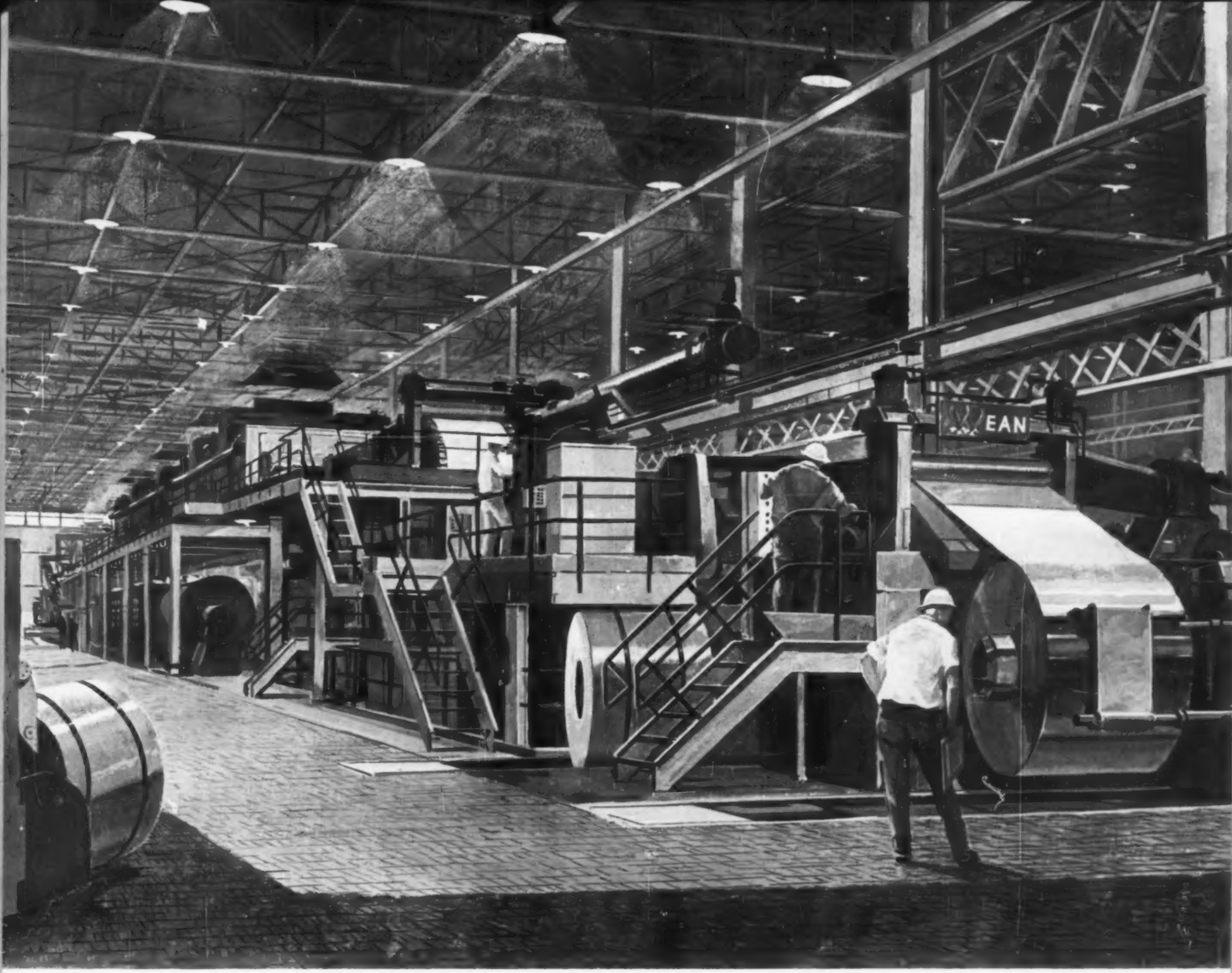
270 Park Avenue, New York 17, N. Y.

UNION CARBIDE



PORTRAIT OF PROGRESS: *Wean Annealing and Pickling Line at Armco Steel Corporation's Butler Works*

Wean Line Part of Armco's Expansion into Wider, Closer Tolerance Stainless

Over the past ten years, Armco Steel Corporation has carried on a multi-million dollar expansion and modernization of its Butler, Pennsylvania plant facilities. One of the latest projects boosts the plant's production of flat-rolled stainless steel, providing customers with wider, closer tolerance stainless sheet and coils.

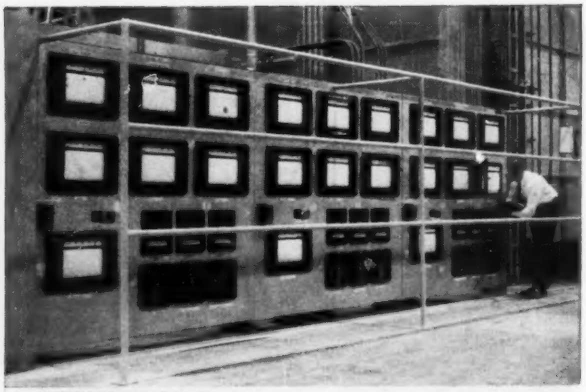
A vital part of this program is represented by the Wean stainless annealing and pickling line illustrated. This line is unique, in that all processing sections are installed above floor level. Above-ground design facilitates inspection and maintenance of the furnace section, acid tanks, and drive mechanisms.

Armco's new Wean line is capable of handling 30,000-pound stainless steel coils from 24" to 52" in width and from .010" to .080" in thickness. The line operates at speeds up to 150 feet per minute. An even flow of materials is maintained in the processing section by two pay-off reels that permit rapid joining of coils.

The Wean "creative engineering" that resulted in these new design features has also been part of the development of annealing facilities for every major steel producer. This background of research and development is ready to help you solve your production and modernization problems.

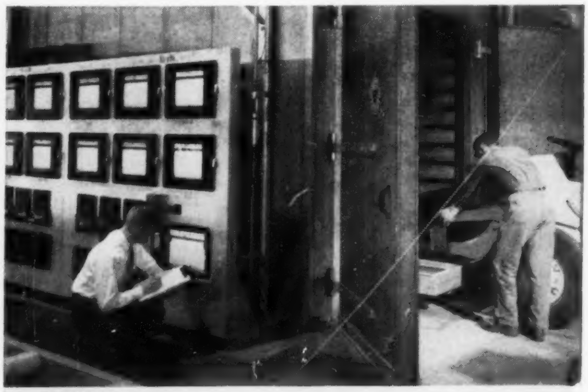
THE WEAN ENGINEERING COMPANY, INC. · WARREN, OHIO

SOAKING. These Bristol Dynamaster* instruments monitor soaking pit operation in new, multi-million-dollar aluminum fabricating plant of Anaconda Aluminum Company at Terre Haute, Indiana. Staff engineer analyzes record.



ANNEALING. Dynamaster* instruments here control and record annealing furnace temperatures in new Anaconda Aluminum plant. Over 11½ acres under one roof, the new plant produces aluminum sheets, extrusions, tubes and ingots.

HEAT TREATING. Anaconda staff engineer checks temperature records, produced by Bristol Dynamaster instruments, for vertical extrusion heat-treating tower, part of which is shown at left.



AGING. Dynamaster instrument panel at left controls and records temperatures in aging furnaces in new Anaconda Aluminum Company plant. Furnace operator at right is moving rack car into furnace.

BRISTOL INSTRUMENTS FOR THE METAL INDUSTRY

The key to higher quality, more uniform production, greater efficiency

Bristol offers pyrometers for every requirement: Electronic potentiometers (including miniature models), millivoltmeter and radiation types... for furnaces, ovens... every type of heating equipment, every kind of fuel.

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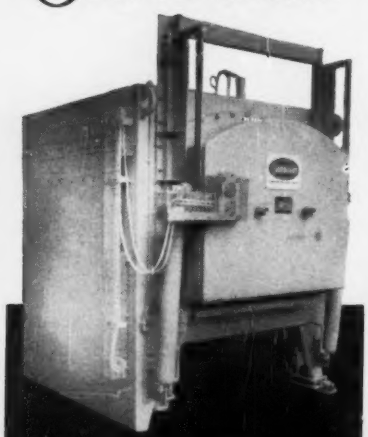
Aluminum Alloys . . .

Static corrosion tests were performed in stainless steel autoclaves. Specimens were completely immersed in deionized water, this water being changed every time specimens were removed for inspection. The maximum time between inspections was one week.

Dynamic tests were carried out in a stainless steel loop in which pressurized water was recirculated at 260° C. (500° F.). Water purity was maintained by ion-exchange, and the velocity of water past the specimens was held steady at 20 ft. per sec.

The method for assessing the amount of corrosion differed for the static and dynamic tests. In the temperature range of 260 to 300° C. (500 to 570° F.), the corrosion product for aluminum-nickel alloys is böhmite ($Al_2O_3 \cdot H_2O$). Weight-gain measurements provided the basis for estimating corrosion. For the dynamic tests, however, weight gains were not sufficiently accurate since some of the corrosion film may be lost by dissolution, spalling, and erosion. Therefore, corrosion penetration was taken as the decrease in average radius of uncorroded metal in the cylindrical specimens. Static tests on alloys No. 155 and 157 in water at 300° C. (570° F.) conducted over a period of 30 weeks showed that corrosion was greater for alloy No. 155; it gained some 11 mg. per sq.cm., while No. 157 gained only some 7 mg. per sq.cm. The attack on No. 155 was less uniform than No. 157. The addition of small amount of titanium, beryllium and zirconium, as in alloy No. 185, gave a similar corrosion rate to alloy No. 157. When "heavy water" was used as the medium, specimens showed less corrosion than for light water.

It has already been established that corrosion rates for aluminum-nickel alloys are higher in dynamic than static tests. It was found that



Aluminum Alloys . . .

the addition of 1000 ppm. of SiO_2 to the water distinctly reduced the corrosion penetration in alloy No. 155, the böhmite deposit being replaced by montmorillonite and kaolinite.

Some investigation was made of the effect of "heat flux". Fuel-element sheathing gets hotter than the circulating water, and the effect of this heat flux must be considered before adopting any alloy for sheathing purposes.

As for mechanical properties, alloy No. 157 is superior to No. 155. Fabrication and welding are also discussed briefly. The type of water-cooled power reactor being developed in Canada is the pressure tube type in which heavy water is used both as moderator and coolant, and uranium dioxide as fuel, using Zircalloy sheathing. From this investigation we find that aluminum-nickel-iron alloys have corrosion rates in static high-temperature water which are very high relative to those of Zircalloy, but very low relative to other commercial aluminum alloys.

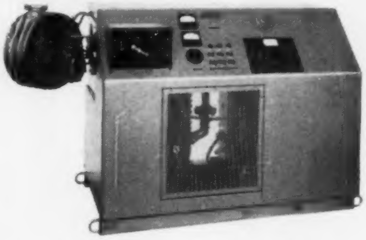
Digested by H. J. Roast from "Aluminum Alloys for Water-Cooled Power Reactors", by E.C.W. Perryman, *Journal* of the Institute of Metals, October 1959, p. 62-73.

Papers invited for . . .

Structure and Properties of Liquid Metals

The Transactions Committe of the American Society for Metals is inviting papers to consider for presentation at its special session "Structure and Properties of Liquid Metals" to be held Nov. 2, 1962, during the 44th National Metal Congress in New York. Papers will be reviewed by the Transactions Committee for acceptance for presentation and subsequent publication in *Transactions Quarterly*.

Manuscripts in triplicate, plus one set of unmounted original photographs and original drawings, should be sent to the attention of John Parina, Secretary, Transactions Committee, American Society for Metals, Metals Park, Ohio. Papers to be considered must be received at Metals Park by May 15, 1962.



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CONCEPT IN HEAT TREATING TECHNIQUE.

'PUNCH CARD' QUALITY CONTROL SYSTEM NOW PERFECTED.

For the first time automatic quality control in heat treating

System completely eliminates factor of furnace operator error

Provides exact record of metallurgical treatment on every job

LINDBERG ROBOTROL

Guarantees you precise uniformity and quality in heat treating

Introduced at the recent ASM Show at Detroit, this new Lindberg Robotrol automatic quality control system has been in development for more than five years. With this punch card system pyrometers, timers, atmosphere control instruments and all the factors on which metallurgical results are dependent are set up and automatically controlled. It is practically impossible for the furnace operator to treat the work improperly.

The punch card also provides an exact record of the treatment given each job. You know exactly what happened.

The Robotrol system is extremely flexible and can be adapted to any kind of heat treating cycle. For full information consult your local Lindberg Field Representative (see classified phone book) or write us direct.

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METAL PROGRESS

THE MAGAZINE OF MATERIALS AND PROCESS ENGINEERING

Volume 80

July 1961 through December 1961

Metal Progress Is Owned and Published by

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Metals Park, Ohio

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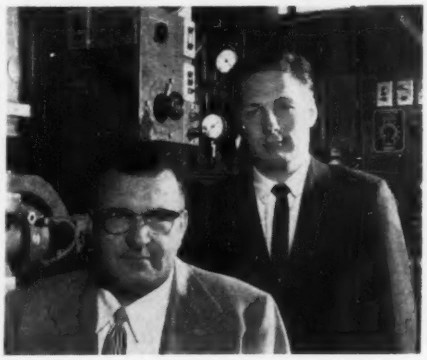
BEHIND THE BYLINES

High-quality seam and spot welds in René 41 can be made consistently, if precautions based on the metallurgical behavior of the alloy are taken into account, according to **B. M. Wahlin** and **D. R. Coles** in their article on p. 67. B. M. Wahlin (shown on the right, below, with Mr. Coles) graduated from the University of Washington with a B.S. degree in mechanical engineering. He has been with Boeing for five years as a materials analysis and welding research engineer and during that time has directed research programs dealing with the basic properties and weldability of new metals and alloys as they relate to airframe components. An ardent golfer (one of his favorite partners is his co-author), he also enjoys working with flowers, shrubs and trees (and has a beautiful yard as a result). He and his wife have two sons.



Another University of Washington alumnus, Coles too received his B.S. degree in mechanical engineering. He has 30 years experience in welding, including seven years at Boeing as a research welding engineer. In addition to golf, his outdoor interests include hunting for deer and elk with his 12-year old son.

Comprehensive tests results on two important new superalloys – Udimet 700 and IN-100 – are reported on p. 73. The first of the superalloys for jet engines, Udimet 700 (a wrought alloy for 1800° F. service) is discussed by **Italo S. Servi** and **William J. Boesch** of Special Metals Inc. in New Hartford, N.Y. (formerly the Metals Div. of Kelsey-Hayes Co.). A write-up of the officers of the new company appeared in the September Personal Mention columns of *Metal Progress* and included some biographical details about Dr. Servi, vice-president of the company. Married, with three children, he is assistant district commissioner of the Boy Scouts of America. Other interests are hiking, electronics, and music.

As manager of the technical services department, Mr. Boesch's responsibilities include supervision of experimental and pilot plant melting and conversion as well as coordinating several development projects. A graduate of Purdue with an M.S. degree in metallurgical engineering, he joined the Metals Div. of Kelsey-Hayes in 1958 as chief metallurgist, assuming his present post two years later. He is married

and has two children, and he too is active in the Boy Scouts as a district commissioner and in several civic programs. For relaxation he plays the organ. Other hobbies include gardening, do-it-yourself projects, golf and bowling.

The application of H11 for aircraft structures (including mechanical properties for the air-melted material) was described in these pages by **P. E. Ruff** nearly three years ago. As soon as the consumable-electrode vacuum melting process became available, its effect on the quality of H11 was investigated. The results are presented here by Mr. Ruff (upper right) and **R. W. Steur** (lower left), engineering specialists at North American Aviation in Columbus, Ohio. A 1948 graduate of Harvard, R. W. Steur came to North American in 1953. He went on to graduate work in Columbus at Ohio State and received his M.S. in metallurgy in 1958. Married, he enjoys model railroading with his son, 6 (his younger children, two daughters, are 3 and 1) and photography.

P. E. Ruff graduated from Ohio State in 1950 with a B.S. and M.S. degree in engineering, then joined North American in 1951. A pioneer in the development of H11 as an aircraft structural material, his work has involved evaluating and processing ferrous and heat-resistant alloys. He and his wife have two sons (9 and 6); his hobbies are carpentry and gardening.

The first technical report on IN-100 was presented in *Metal Progress* earlier this year. **S. F. Sternasty and E. W. Ross** (right to left in the photo below) give the results of G.E.'s study of the alloy for turbine blades on p. 73. Stan Sternasty, an engineer in the structural materials unit of the Large Jet Engine Dept. in Cincinnati, Ohio, joined the department in 1959 and has been engaged primarily in development, evaluation and application of turbine blades. A 1954 graduate of Illinois Institute of Technology, his background includes experience in the steel industry. His former secretary (now his wife) permits him to follow one hobby (barbershopping) and encourages him in another (amateur cabinet making).

A specialist in the development and application of materials for jet engines, Earl W. Ross is supervisor of the structural materials unit. After receiving his B.Met.E. from the Polytechnic Institute of Brooklyn in 1946, he was an instructor in metallurgical engineering and a part-time graduate student at the Polytechnic. His work for G.E. includes two years working on metallurgical problems for the rotating components on the nuclear jet engine. He was transferred to the structural materials unit where he was responsible for further development of turbine blade alloys such as DCM, and has served two years as supervisor of this unit. He, too, married his secretary and they have three sons – aged 2, 4 and 6. He's interested in sports (both as a spectator and an active participant), reading and community relations activities.

Investigations of elevated-temperature mechanical properties of metals under rapid strain rate and short times at temperature conducted at Southern Research Institute, Birmingham, Ala., are the basis of **J. R. Kattus'** article on p. 85. On the Institute's staff since 1952, Bob Kattus is head of the metallurgy division, where his work has included supervision of research projects on cast and wrought steels, nonferrous alloys, cast iron, aircraft structural materials and refractory metals. He studied metallurgical engineering first at the University of Cincinnati and then Purdue, where he received his B.S. degree in 1944. He moved to Birmingham in 1948 as chief metallurgist for Anderson Brass Works. Active in several technical groups, including A.S.M. and A.S.T.M., he is past chairman of the Birmingham Chapter. Although his four children – three daughters and a son – seem to occupy most of his spare time, he enjoys golf and bridge. He's also an enthusiastic big league baseball fan, rooting particularly hard for the Reds since Cincinnati is his home town.

"How Composition Affects the Properties of Ductile Iron" on p. 92 is the work of two professors at Case Institute of Technology, **John F. Wallace** and **Lynn J. Ebert** (right to left in the photo). Professor of metallurgy at Case since 1953, John Wallace received his B.S. (1941) and M.S. (1953) degrees from Massachusetts Institute of Technology. He worked for 13 years at Watertown Arsenal in various metallurgical and production capacities, including director of the Rodman Laboratory. When time permits, he enjoys swimming and engaging in sightseeing activities with his family (he has three children).

Dr. Ebert joined the faculty of Case in 1941 as a graduate assistant after obtaining his B.S. degree there. In the intervening years he has

risen to associate professor in the department of metallurgy and obtained two more degrees, his M.S. (1943) and Ph.D. (1954) in addition, he is also executive officer of the department of metallurgy at Case. Working in metallurgical research, primarily in the area of mechanical metallurgy, he has contributed to the development of the notched tensile test and the evaluation of heat treated alloys by means of this test, stress distribution studies by x-ray techniques, the mechanism of low-temperature brittleness, directionality in metals and fatigue behavior. Married, with four children, his hobbies include golfing and landscaping, as well as occasional trips to the lake country of northern New York.

An extensive study of the effect of ferrite on mechanical properties and resistance to stress corrosion in 18-8 stainless and other alloys resulted in the article on p. 99 by **Mars G. Fontana, James W. Flowers** and **Franklin H. Beck** (shown, left to right). Jim Flowers came to Ohio State University in 1958, following graduation from the University of Cincinnati with a B.S. degree in metallurgical engineering, and is now

working toward his Ph.D. in the same field. His research activities have centered around precipitation processes in cast stainless steels. Among his other interests are sports, reading and hi-fi.

After receiving his B.S. degree in metallurgical engineering from Pennsylvania State University in 1943, Frank Beck worked for E. I. du Pont de Nemours & Co. for two years, then continued his education at Ohio State where he earned his M.S. and Ph.D. degrees in metallurgical engineering. He has been on the staff of the University since 1949, devoting his time primarily to research in corrosion of metals, and is now professor of metallurgical engineering and director of metals research at the Engineering Experiment Station. The Becks have two sons and a daughter. One of Frank's other concerns is Boy Scout work.

Mars Fontana received a B.S. degree in chemical engineering and an M.S. and Ph.D. in metallurgy, all from the University of Michigan. He was on the staff of the engineering department of DuPont from 1934 to 1945, and since 1948 has been chairman of the department of metallurgical engineering at Ohio State. Well known to A.S.M. members, he is past chairman of the Columbus Chapter and has served on many local and national committees.

His family includes two daughters, two sons and a grandson and his hobbies are bowling, golf (best ever, 75 last summer), manicuring lawns and hunting white-tailed deer (eight bucks in ten years). He is widely known as One-Shot Fontana in the Upper Peninsula of Michigan – and has an engraved certificate to prove it. His greatest feat was dropping an eight-pointer with open sights at 176½ yards.

John G. Wilson, plant manager at Eaton Mfg. Co.'s Marion (Ohio) Div., describes automatic forging of steel gears on p. 108. Born and educated in Northern Ireland, he graduated from Belfast Technical College. Coming to the United States in 1949, he joined Eaton in 1951. He lists hunting, fishing, golfing, and camping with his wife, Joan, and two sons, Mike and Johnny, as his favorite pastimes.

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METALGRAMS

UNION CARBIDE METALS

. . . news of "Electromet" ferroalloys and metals

DECEMBER 1961

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* * *

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